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AFIT/GCA/LSY/88S-7

ANALYSIS OF COST GROWTH AND COST COMPOSITION IN THE DEFENSE AEROSPACE INDUSTRY

THESIS

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AFIT/GCA/LSY/88S-7

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THESIS

Presented to the Faculty of the School of Systems and Logistics

of the Air Force Institute of Technology

Air University

In Partial Fulfillment of the

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Master of Science in Cost Analysis

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Thomas M. Obringer

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Abstract

The objectives of this study were to determine if "real" cost growth occurred in the defense aerospace industry during the period 1980 to 1986 and if the percentage of overhead costs to total cost increased during the same period. The study tested two hypotheses: 1) costs increased in the defense aerospace industry during the period 1980 through 1986; 2) the percentage of overhead costs to total cost increased in the defense aerospace industry during the period 1980 to 1986. Cost data from sixteen defense aerospace plants were used in this study.

The results of both primary hypothesis tests indicate that the slope of the population regression lines are not significantly different from zero (when tested at the 5% level of significance). Therefore, the study concludes that there was no "real" cost growth in the industry during the period 1980 to 1986 and that overhead costs did not increase relative to total cost during the same period.

However, when contractors are tested individually, the results indicate that eight of the sixteen contractors experienced significant cost growth. The conflicting results may be due to the wide dispersion of the data points used in the statistical tests. In turn, this wide dispersion may be caused by the differing variety of aerospace industry segments. For example, the aircraft industry segment may be

subject to a different set of factors that have a significant influence on cost than that of the guided missiles and space vehicles segment.

Descriptive statistics computed for the study's sample of 16 contractors show that the percentage of direct labor, direct material, other direct charges and overhead to total cost remained stable over the seven year period. This stability was not expected because it was assumed that Department of Defense (DOD) contractor modernization incentives would change the composition of total cost. The results of this study indicate that any modernization of defense aerospace factories that occurred before 1986 was not significant enough to generate changes in the composition of this sample's costs.

Although overhead costs were not found to be increasing relative to total cost, they still make up the second largest component of total cost (32%) behind direct materials (42%). The size of the overhead cost component combined with the perception that these costs are less controllable than direct costs, provides support to the DOD initiative to have contractors reduce their overhead costs.

ANALYSIS OF COST GROWTH AND COST COMPOSITION IN THE DEFENSE AEROSPACE INDUSTRY

I. Introduction

General Issue

Concern for Cost Growth. The cost of national defense is always an issue in a democratic country. As Anthony points out in *Management Control In Nonprofit Organizations* (2), decisions in a democratic government result from multiple political pressures. These political pressures divide the limited resources of a country (2:51). The United States is no exception. As a major military power of the free world, it shoulders a heavy financial burden. The Department of Defense (DOD) is responsible for managing a major portion of this burden.

In recent years, the taxpayers' perception of defense spending has changed. According to a survey completed in 1985 as part of the President's Blue Ribbon Commission on Defense Management, the average American believes that almost half (46%) of every defense dollar spent could be saved if fraud and waste were eliminated. Additionally, the survey reported that only 14% of the public believe that defense spending should increase compared to 71% who favored spending increases in 1980 (28:29).

In addition to public attitudes on defense spending, the large federal deficit looms as another barrier to liberal

defense budgets. It is clear from the 1988 budget and the comments of the President and legislative leaders that deficit reduction has become a goal of the country (20:31). Public Law 100-119, "Balanced Budget and Emergency Deficit Control Act" (Gramm-Rudman-Hollings, 1985), is a specific example of how serious the nation's leaders are about achieving this goal.

According to Secretary of Defense Carlucci, the military will receive its share of budget reductions (13:49). These reductions will come at a time when weapon systems cost more than ever. For example, in 1954 the United States ordered 6300 fighters for $7 billion (in 1983 dollars). In 1984, it paid $11 billion (in 1983 dollars) to produce only 322 planes (10:64). The price of a fighter increased from $11.1 million in 1954 to $34.2 million in 1984--a 308 percent increase as measured in constant 1983 dollars.

Much of the cost growth in weapon systems can be attributed to increased complexity and technological capabilities (10:64). However, not all of the cost increases can be associated with technological requirements. A 1980 Defense Science Board task force reported that weapon system costs may be increasing by as much as 20 percent per year due to economic (inflation) and government budgetary policy factors (29:1).

A major issue that faces the Department of Defense for the remainder of the 1980s and into the 1990s is cost control (33:22). To achieve this, weapon system program managers must

understand the composition of contractors' costs and how they are generated. Deputy Secretary of Defense Taft believes that much can be gained in the way of cost reductions by addressing the major components (direct and indirect costs) of contract cost (3:24).

Cost Components. Weapon system contract costs consist of direct and indirect costs (12:31-7). The Cost Accounting Standards Board (CASB) defines a direct cost "as any cost which can be identified with a particular final cost objective" (7:5112). Indirect or overhead costs are defined by the CASB as "any cost not directly identifiable with a single cost objective, but identified with two or more final cost objectives or with at least one intermediate cost objective" (7:5308). Additionally, a cost objective is "any activity for which a separate measurement of cost is desired" (16:21). In the defense industry, the contract is the final cost objective (19:7).

Overhead is often cited as comprising one third of the total contract price of a weapon system (34:24). More importantly, overhead costs are viewed as being more difficult to manage than direct costs (8:87). Trueger points out that accounting for indirect costs for government contracts has "always posed the most difficult problems and generated the most controversies" (35:277). In addition, many experts believe that there is a trend of increasing indirect costs in manufacturing industries as a consequence of factory automation (22:142).

Deputy Secretary of Defense Taft believes that reduction of overhead costs is an important cost control initiative. Secretary Taft wants top management to ensure that "adequate personnel resources are applied to this area, (overhead cost control) not only in numbers but in talent" (3:25).

Specific Problem Statement

There is a perception on the part of the public that unacceptable cost growth exists in the defense industry (28:29; 32:22). In addition, federal deficit reduction initiatives are generating smaller Defense Department budgets. As a result, DOD managers must be more concerned with controlling the cost of weapon system acquisitions. According to Deputy Secretary of Defense Taft, one important cost control initiative is the DOD's effort to have contractors reduce overhead costs (34:24).

To help achieve overhead cost reductions and better control costs, managers need to know and understand past weapon system cost trends. The more program managers know about cost behavior in the aerospace industry, the more effective they will be at controlling program costs. Therefore, this research investigates the trends of defense aerospace industry costs during the 1980s.

Research Objectives

This study confines its research to the defense aerospace industry. The research objectives are to determine if "real" cost growth occurred in the industry during the period 1980

through 1986 and if the percentage of overhead costs to total cost increased during the same period. In other words, have costs increased in "real" terms and, if so, is the overhead component disproportionally responsible for any of the growth?

Research Hypotheses

Two hypotheses are proposed to meet the research objectives.

Hypothesis number one, costs increased in the defense aerospace industry during the period 1980 through 1986.

Hypothesis number two, the percentage of overhead costs to total cost increased in the defense aerospace industry during the period 1980 through 1986.

Scope/Limitations

Scope. This study investigates the costs of defense aerospace contractors under U. S. Air Force cognizance. The annual costs of 16 contractor plants for the years 1980 through 1986 are used in the research. The source of the cost data is the Business Management Information Report (BMIR), Report Control Symbol (RCS): CMD-TM (A/R) 7801 filed with the Business Management Office (BMO) of Head Quarters Air Force Contract Management Division (HQ AFCMD).

Limitations. The cost data in the BMIRs are proprietary. As such, very few contractor specific statistics are printed in this thesis. Permission to view such statistics must be obtained from the Business Management Office, office symbol: HQ AFCMD/TMO, Kirtland AFB NM 87117-5000.

The cost data used in this thesis relate to production plants and facilities, including their allocated share of general and administrative expenses. No conclusions can be drawn from this research as to trends in the costs of aerospace research and development projects.

There are probably differences in the way the contractors in this sample classify and account for their direct and indirect costs. This study does not adjust for these differences. However, the Cost Accounting Standards followed by the contractors and periodic Defense Contract Audit Agency reviews should help minimize cost accounting differences.

The cost data analyzed in this study pertains to contractor plants. No attempt is made to link these costs to specific government contracts. It is assumed that if a contractor's costs grew over time, he would recoup these costs through contract price increases.

Finally, the period of this study is limited to the years 1980 through 1986 because comparable cost data are not available for other years.

Summary

This chapter identifies the problem of weapon system cost control as the specific issue of this thesis. It also points out the DOD contention that reductions in overhead costs are an important cost control initiative. Knowledge of historical weapon system cost growth trends can help managers control costs. This chapter introduces the study's two hypotheses

that are tested to meet the thesis objectives of identifying cost growth and overhead growth trends in the defense aerospace industry.

The next chapter discusses the literature reviewed and presents the background for the study.

II. Background

Introduction

The concern for cost control in the defense industry was previously identified as the specific issue of this thesis. A major DOD cost control initiative is the effort to have contractors reduce overhead costs. Awareness of past weapon system cost trends is necessary to better understand cost incurrence and to help control these costs. Therefore, the objective of this study is to determine if "real" cost growth occurred in the defense aerospace industry during the 1980s and if the percentage of overhead costs to total cost increased during the same period.

This chapter presents the study's background in four sections. First, the term "cost" is defined and explained. Second, the issue of cost responsibility is discussed. The third section examines the perception of cost growth and cost composition in the defense industry. Finally, three empirical studies of cost growth and composition are summarized.

Cost Defined and Explained.

The word "cost" has different meanings to different people. Because cost is such an ambiguous term, it is important to clearly define it and to specify how it is measured. This is especially important for situations in which the buyer agrees to reimburse the seller for goods or services based on the seller's cost (1:107-108). This section defines what "cost" means as used in accounting for government

contracts and explains the fundamental principles of measuring and accounting for cost.

Cost Defined. The Federal Acquisition Regulation (FAR) makes the following statement about a contract cost:

> In ascertaining what constitutes a contract cost, any generally accepted accounting method for determining or estimating costs that is equitable and consistently applied may be used, including standard costs properly adjusted for applicable variances [12:31-7].

Generally accepted accounting methods or principles are a "common set of accounting concepts, standards, and procedures . . . that act as a general guide for the accounting profession" (17:7). Accounting Principles Board (APB) Opinions are one source of generally accepted accounting principles (17:6). APB Opinion Number 43 defines cost as follows:

> the price paid or consideration given to acquire an asset; it includes the applicable expenditures and charges directly or indirectly incurred in bringing the asset to its existing condition and location [9:27525].

The definition of cost provided by the APB will suffice for this study since neither the FAR nor the CAS provide a specific definition of cost. The next subsection explains the composition of weapon system costs.

Cost Explained. Weapon system contract costs are made up of two components--direct costs and indirect costs (12:31-7). The official government definition of the direct cost component as stated in Cost Accounting Standard (CAS) 402 and the FAR reads as follows: "a direct cost is any cost which can be identified specifically with a particular final cost

objective" (12:31-202). Direct costs, in turn, are categorized as direct labor, direct material, and other direct charges (35:267).

The direct labor cost category is the cost associated with the time workers use to generate output for the specific cost objective. The direct material category is the cost of raw materials and purchased parts that are used for the final cost objective (23:42). The other direct charges category contains those costs other than direct labor or materials that can be directly identified to the cost objective (35:267).

The second cost component is indirect or overhead costs (for this study, indirect and overhead are synonymous terms). The CASB provides the following definition of indirect costs: "any cost not directly identified with a single cost objective but identified with two or more final cost objectives or with at least one intermediate objective" (7:5308).

Total overhead includes not only indirect manufacturing and facilities costs incurred in the plant, but also an allocated portion of general and administrative costs that are incurred outside the plant by the home office (1:242). Government contracts include an additional allocation of indirect cost classified as Independent Research and Development (IR&D) and Bid and Proposal (B&P) costs (35:277). IR&D costs are the cost of research and development that are not required in the performance of a contract but benefit the contract to some degree. B&P costs are incurred in preparing bids and/or proposals for government contracts (7:5725-5726).

Unlike the direct cost component which has three standard categories (direct labor, direct material, and other direct charges), the overhead component has many categories which may vary between contractors (35:277). Indirect costs are also associated with more than one final cost objective. Indirect costs must first be accumulated into cost pools, which are management devices for collecting similar costs, and then allocated to the cost objectives (1:190).

"An allocation is simply a proportional assignment of a cost to cost objectives" (8:85). These allocations are made on a "judgmental basis" by applying an overhead rate to the cost pool to arrive at the amounts to be allocated to the cost objectives (23:30). CAS 418.40 states that "pooled costs shall be allocated to cost objectives in reasonable proportion to the beneficial or causal relationships of the pooled costs to cost objectives . . ." (7:5697).

Figure 1 summarizes the composition of contract cost. There are two cost components--direct and indirect. Direct costs are identifiable to a particular cost objective and are categorized as direct labor, direct materials, and other direct charges. Indirect costs are identifiable to two or more cost objectives and are allocated to the applicable objectives based on some beneficial or casual relationship. There are many categories of indirect costs, but four standardized categories are used in this study. These categories are labor related costs, travel costs; depreciation, use, and occupancy costs; and other costs.

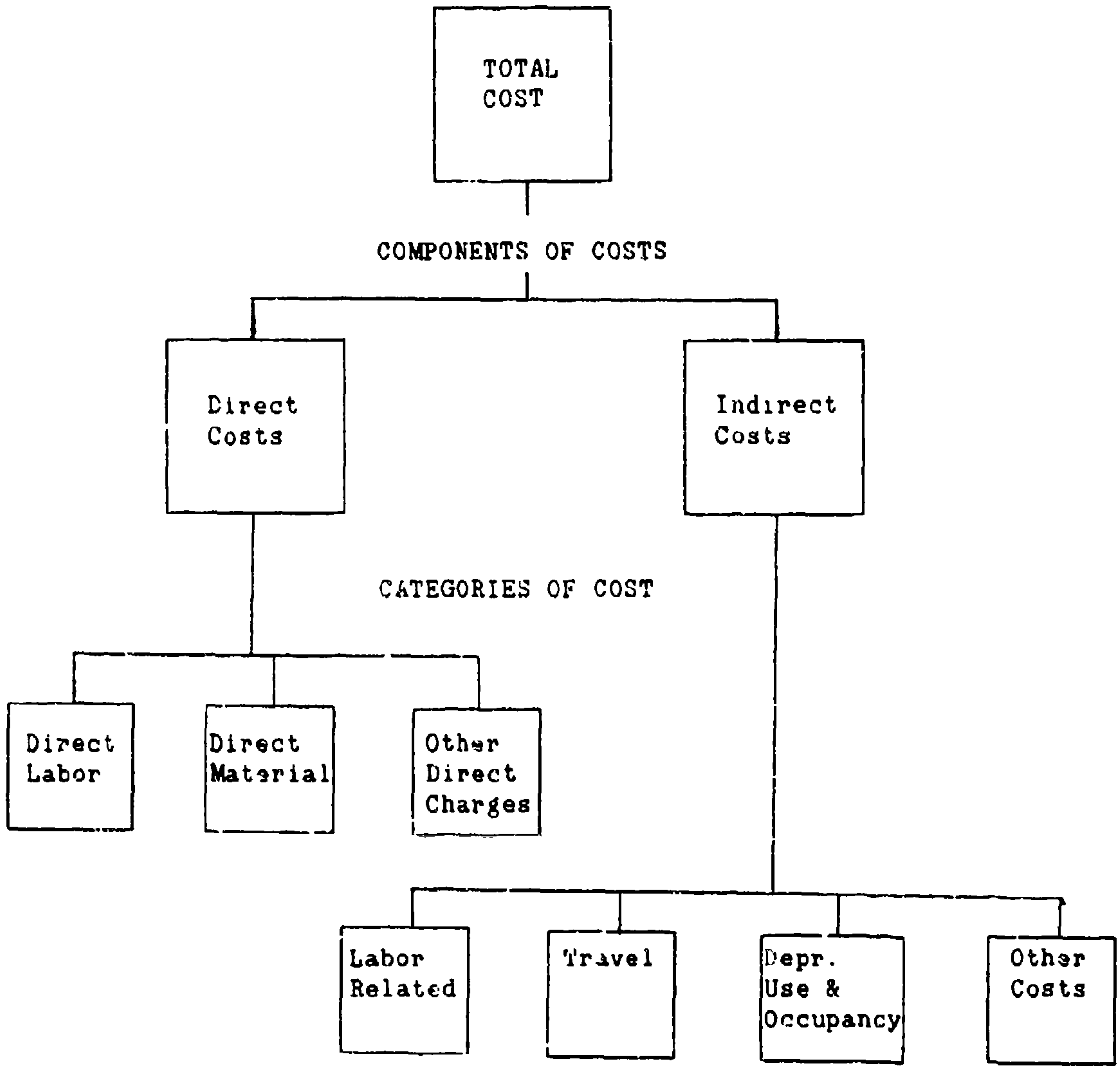

Figure 1. Contractor Cost Composition

Cost Control

Cost Responsibility. Organizations employ a variety of techniques to control and manage their costs. In addition, large government contractors must follow a number of regulatory guidelines promulgated in the Cost Accounting Standards and the Federal Acquisition Regulations, and requirements in the DOD Cost/Schedule Control Systems Criteria (35:164; 19:3).

An important aspect of cost management and responsibility is the issue of controllable and noncontrollable costs. "An item of cost is controllable if the amount of cost assigned to a responsibility center is significantly influenced by actions of the manager of the responsibility center. Otherwise it is noncontrollable" (1:591). Therefore, the classification of costs as controllable or noncontrollable depends on who is responsible for incurring the costs.

Cost and management accounting texts indicate that the responsibility for cost management lies with the company because the company has control over incurring costs. However, in the defense industry, the government seems to assume a portion of the responsibility for cost control. Trueger highlights this contention by stating "the government's intensive and extensive participation in the affairs of its contractors has virtually no counterpart in the commercial sector" (35:189). The government lays the ground rules for contractor selection; audits the contractors'

facilities, records, and books; establishes contract cost principles and practices; mandates certain insurance coverage; and may even dictate whether a component of the final product should be manufactured or purchased (35:189-190).

Riddell also recognizes that the heavy influence of government in the defense sector makes the industry unique from other business sectors (30:452-453). Riddell is particularly critical of the "boom and bust cycles" generated by congressional budgetary actions that create weapon program instability and generally drive up unit costs (30:456).

The above discussion indicates that the responsibility for cost control does not lie solely with defense contractors. Such an environment may not support effective cost management because the responsibility for cost control is not well defined.

Cost Control. Trueger explains that direct costs are easily and economically traceable to a cost objective. The extent to which costs are directly identified and assigned to the final cost objective is "tempered by considerations of expense, convenience, and practicability" (35:267). In other words, there is a cost-benefit decision associated with classifying costs as direct or indirect. Since direct costs benefit a single cost objective, they are not as difficult to control as indirect costs (1:591-592).

However, since indirect costs are allocated to more than one cost objective, they are less controllable than direct

costs (1:591). According to Deakin and Maher, indirect cost are not only less controllable than direct costs, but the allocation of these costs to cost objectives is often made on a rather arbitrary basis. Critics of cost allocation claim that it results in misleading financial reports and poor management decisions (8:87).

Miller and Vollman claim that results of their 1985 survey of North American manufacturers, show that most managers understand what generates direct labor and direct material costs, but are much less aware of what generates overhead costs (22:143). For this reason, overhead is often misunderstood and debated.

Trueger explains that allowability of indirect costs has generated the most difficult problems and controversies in accounting for government contracts. In fact, most of the government contract cost principles are dedicated to the coverage of indirect costs (35:143).

The Comptroller General's "Report on the Feasibility of Applying Uniform Cost Accounting Standards to Negotiated Defense Contracts" states the following about indirect costs:

> Indirect costs, in the aggregate, represent the largest single class of expense incurred under Government contracts. The allocation of indirect costs is one of the most controversial in cost accounting for Government contracts and is subject to alternative approaches. It is not a problem that can be solved by simple or rigid rules. Indirect cost assignments of necessity cannot be as accurately determined as direct ones, but they still must be based on some demonstrable relationships between the reasons why costs were incurred and the cost objectives to which they are assigned [35:280].

Perceptions of Cost Growth and Cost Composition

Many articles exist that address weapon system cost growth and composition. The following sections provide a brief review of these articles. Tables 1 and 2 summarize the articles' key assertions on cost growth and cost composition respectively.

Cost Growth. A 1985 survey conducted as part of the President's Blue Ribbon Commission on Defense Management indicates that the American public believe the defense industry has experienced unacceptable cost growth. Additionally, those surveyed think the Defense department is wasting almost $100 billion a year (28:29).

Some individuals who study the defense industry also conclude that costs in the industry are "dramatically" increasing. Olvery et al., in their book The Economics of National Security (26), state that "there is no doubt that the price of weapon systems have increased dramatically over the past several decades." The authors see no reversal of this trend in the near future (26:229). Gansler believes that rising weapon system costs will continue to plague the DOD due to a variety of factors peculiar to the defense industry (11:226).

Gansler cites such problems as high excess industry capacity levels, insufficient levels of capital investment, and technologically complex weapon systems for the high rates of cost growth. He also expects weapon system costs to continue to increase because of the near term trends of

Table 1

Summary of Cost Growth Assertions

Author	Year	Assertion	Citation
Jacques Gansler, author of The Defense Industry	1980	Cut backs in Defense spending, low capital investment, and other industry peculiarities will lead to rising weapon system costs.	11:228
Tom Riddle, Professor of Economics, Smith College	1984	The structure of the defense industry precipitates expensive weapon systems and drives cost growth.	29:454
Olvey, Golden, and Kelly, authors of The Economics of National Security	1984	There is no doubt that the price of weapon systems has increased dramatically over the past two decades (1960s and 1970s) and this trend will probably continue.	25:229
Congressional Budget Office	1985	Annual cost growth of selected weapon systems has been reduced from 14% in calender year 1980 to 1% in calender year 1983.	33:21
Rand Corporation	1986	Cost growth in the defense sector is now no greater than in civil programs of similar size and complexity.	18:24

Table 2

Summary of Overhead Cost Assertions

Author	Year	Assertion	Citation
Jacques Gansler, author of *The Defense Industry*	1980	DOD overhead rates are higher than U.S. manufacturing industry norm. Overhead costs and rates will continue to rise for weapon systems.	11:170, 226
Thomas Bowman, Maj., USAF	1982	Overhead costs account for more than 50% of total contract completion costs and have approached 75% in inflationary times.	5:1
Thomas Mahler, Maj., USAF	1984	DOD indirect costs are large and volatile and are usually incurred as a function of time rather than as a function of a contractor's direct work load.	19:13
Deputy Secretary of Defense William Taft	1985	Overhead costs make up roughly one third of the price paid for weapon systems. The reduction of overhead costs is an important DOD cost control initiative.	35:21
Jeffery Miller and Thomas Vollman, Professors, Operation Management Boston University	1985	Overhead averages 35% of production costs in U.S. manufacturing and the percentage has been rising for the past 100 years.	21:41-42

smaller defense budgets, fewer subcontractors, dependence on foreign raw materials, and increases in excess industrial capacity (11:224-227).

Riddle argues many of the same points as Gansler and explains that "the services' emphasis on very high performance specifications for technologically sophisticated weapon systems disregards the importance of the cost criteria" (Riddle:454).

However, recent studies seem to contradict public opinion. Cost growth in the defense industry may actually be leveling off in the 1980s after cost overruns of 50 to 70 percent in the 1970s (Riddle:455). A 1986 Rand study concludes that cost growth in defense programs is now no greater than cost growth in similar civil programs (18:24). In addition, the Congressional Budget Office has "estimated that annual cost growth on selected major systems has been reduced from 14 percent in calender year 1980 to only one percent by the end of calender year 1983" (34:21)

The literature indicates that weapon systems experienced significant cost growth in the 1960s and 1970s. Some believe that this trend continues in the 1980s. However, there seems to be some evidence that the significant cost growth of the past may be slowing in the 1980s. The next section presents the background on cost composition of the past five to ten years.

Cost Composition. Since the beginning of the industrial revolution, machines have been replacing direct labor. The

mechanization of the work force has been changing the composition of cost (direct and indirect) and continues to influence cost composition today. The direct labor content of total costs has appreciably decreased in favor of indirect costs (32:45).

Miller and Vollman explain that overhead costs have been steadily increasing as a percentage of total manufacturing costs for more than 100 years (22:142). Results of a survey administered by Miller and Vollman indicate that manufacturing overhead averages 35 percent of production costs in U.S. industry (22:143).

Results of another survey conducted by Harry Schwarzbach shows that levels of indirect costs range from 2 to 67 percent. Indirect costs averaged 29 percent of total manufacturing costs for the 112 manufacturing companies surveyed. Most companies reported direct materials as the largest cost component (31:47).

The perception of cost composition in the defense industry varies among "experts." Deputy Secretary of Defense Taft believes overhead costs make up about one third of the price paid for weapon systems (34:24). Bowman asserts that "overhead costs account for greater than 50 percent (and in inflationary times has approached 75 percent) of total contract completion costs" (5:1). Mahler states that overhead costs are large and volatile and increase more as a function of time rather than contractor direct workload (19:13).

There is little disagreement, however, that overhead costs are a problem in the defense industry. Riddle believes that the structure of the defense industry results in a tendency for overhead costs to increase (Riddle:454). Gansler points out that the industry's high levels of excess capacity drive up overhead costs. He predicts that as defense spending decreases, weapon system overhead costs and total costs will increase (11:226). Deputy Secretary of Defense Taft places "special emphasis" on efforts to reduce overhead costs because they are a significant cost control problem (34:24).

Empirical Studies

During the course of the literature review, a number of cost studies were examined and three of the most applicable are discussed in this section. Table 3 provides a summary of each study.

Martinson Study (21). The earliest study, Classification System for Indirect Costs of Defense Contractors in the Aircraft Industry (21), was completed in 1969 by Major Otto Martinson. This study was sponsored by the Office of Assistant Secretary of Defense (Installations and Logistics). The objective of the research was to develop a standard classification system for indirect costs to "provide an improved methodology for evaluating and forecasting indirect costs." The need for such a classification system was driven by the problem of analyzing contractor overhead cost data when there exists such a large variety of overhead account categories. The study covered the period 1962 to 1966.

Table 3
Summary of Empirical Cost Studies Reviewed in the Second Chapter

Study	Period of Study	Sample	Cost Growth	Overhead Costs
I.	1962-1966	11 Aircraft Manufacturing Plants	Not an objective of the study	A. Total cost average composition: Direct Labor = 18.3% Direct Material = 45.9% Overhead = 35.9% B. Overhead cost average composition: Labor Related = 57.1% Facilities = 16.5% Travel/Comm = 3.4% Other = 23.0% C. The % of Overhead Costs to Total Cost remained stable over the period.
II.	1961-1977	21 Industries as Defined by SIC Codes	A. Aircraft industry costs grew at an annual rate of 8.6%.	A. Total cost average composition in the aircraft industry from 1961-1965: Direct Labor = 16% Direct Material = 46% Overhead = 38% B. Total cost average composition in the aircraft industry from 1973-1977: Direct Labor = 13% Direct Material = 45% Overhead = 42%
III.	1977-1980	5 USAF aircraft Production Programs	A. Cost Growth: 1978-1979: 11.9% 1979-1980: 17.6% B. Contribution to cost growth: 78-79 / 79-80 DL 6.9% / 6.9% DM 49.7% / 58.9% OH 43.4% / 34.2%	A. Total cost average composition: 1978 / 1979 / 1980 Direct Labor 10.4% / 10.4% / 10.0% Direct Material 49.1% / 48.8% / 50.1% Overhead 40.4% / 40.9% / 39.9% B. Overhead cost average composition: Labor Related = 66% Other = 33%

Note:

DL = Direct Labor; DM = Direct Material; OH = Overhead
I. Martinson Study; II. Kaitz and Associates Study; III. Coopers and Lybrand Study

Population/Sample. The population of the study is the aircraft industry. Martinson's sample consists of 11 contractor plants that produced aircraft products. Three of the plants produced jet engines, two produced avionics, and six produced airframes. During the study's time frame, these 11 plants employed about 41 percent of the aircraft industry's work force.

Summary of Methodology. The data collection involved field visits to nine of the subject plants to gather information on their cost accounting structures and indirect cost classifications. The Defense Contract Audit Agency (DCAA) was employed to gather the cost and operating data from each plant. Detailed instructions for collecting the cost data were prepared by Martinson and provided to the resident DCAA auditors at the contractor plants.

The analysis involved two phases. The first was a comparative analysis of the cost accounts and accounting procedures used in the plants to determine the best indirect cost classification mode to use. In other words, should costs be classified by the nature of the costs consumed, by the nature of the process consuming the costs, or by the organizational units consuming the costs? The second phase developed applications for the indirect cost classification system. Descriptive statistics of the sample's costs were computed, a price deflator for overhead costs was constructed, and a regression model was developed to demonstrate the applications of the standard overhead classification system.

Results. The primary result of this research was the development of 11 standardized overhead "cost modes" or categories. These categories are indirect labor, employee benefits, payroll taxes, employment, communication and travel, production related, facilities--building and land, facilities--furniture and equipment, administration, future business, and other miscellaneous.

The descriptive statistics showed that direct labor comprised 16 percent of total cost; direct material 48 percent; and overhead 36 percent. 57 percent of total indirect costs (21 percent of total costs) are composed of labor related expenses--indirect labor, employee benefits, and payroll taxes. Facilities costs are the second highest, averaging 16.5 percent of total annual indirect costs. The cost categories of communication and travel, administration, future business, and other miscellaneous make up the remaining 26.5 percent. Indirect costs as a percentage of total costs increased by 1.5 percent from 1962 to 1966.

Kaitz and Associates Study (27). This study is entitled Overhead Costs and Rates in the U.S. Defense Industrial Base (27) and was completed by Edward M. Kaitz and Associates (KA) for the Office of Naval Research in October 1980. It was performed to "explore the structure of overhead costs and rates within U.S. industry in order to provide the military acquisition manager with a better understanding of the organization and dynamics of the industrial structure on which he relies." The study covers the years 1961 to 1977.

Population/Sample. The population of this study is the defense aerospace industry. The KA researchers obtained their sample data from the Department of Commerce. Twenty-one different industries are included in the study as defined by their Standard Industrial Classification (SIC) code. A detailed analysis of the aircraft industry (SIC codes 3721--aircraft and 3724-- aircraft engines) was completed as part of this study.

Summary of Methodology. The cost data are collected by SIC codes. As such, the cost data are highly aggregated and contain no specific information on either overhead costs or rates. To facilitate their investigation, given the available data, the researchers use the following definition of overhead cost:

$$\text{Overhead Cost} = \text{Sales} - (\text{Direct Labor} + \text{Direct Material}) \quad (1)$$

Note that the study's definition includes profit as a part of overhead. KA justify their definition by arguing that most accounting systems are uniquely tailored to an individual company. By establishing a more broad definition of overhead, the study portrays "more general industrial and economic trends."

The cost data are organized around the concept of the "statistically average production line worker" and the

resources used to support him. This technique results in a total cost per production worker computed as follows:

$$\text{Resources Used Per Worker} = \text{Total Industry Sales} \div \text{Total Direct Labor} \quad (2)$$

KA then break the "resources used per worker" figure into 1) workers wages; 2) material; and 3) overhead (including profit).

Results. The study's aircraft industry data show that for the years 1961 to 1965, 17.5 percent of every sales dollar is attributable to direct labor, 46.8 percent to direct materials, and 35.6 percent to overhead and profit. However, for the last five years of the study (1973 to 1977) the cost composition changes. Direct labor drops to 12.7 percent of every sales dollar, direct materials remain relatively steady at 45 percent, and overhead and profit increase to 42.24 percent. Energy costs, supplementary wage costs (fringe benefits and payroll taxes), and corporate profits were found to be increasing the fastest over the period 1961 to 1977.

The data indicate that costs in the aircraft industry grew at an average annual rate of 8.6 percent. Of this increase, direct labor contributed 24.3 percent, direct materials 34.3 percent, and overhead 41.3 percent.

KA concluded that, for the period studied, the increase in overhead rates (overhead divided by direct labor) were greater than they anticipated. They believed that factors of production other than indirect labor drove up overhead costs.

Further, they thought that production line wages had a minor impact on industry cost growth. Other costs such as overhead and material costs rose much more rapidly and should be regarded as key factors in driving up unit prices in the aerospace industry.

Coopers and Lybrand Study (29). This study, Review of Price Changes in Department of Defense Weapon Systems (29), was a subcontracted effort by Coopers and Lybrand (CL) for The Analytical Sciences Corporation (TASC). It was directed by the offices of the Undersecretary of Defense (Research and Engineering) and the Assistant Secretary of Defense (Comptroller). The study reviewed price changes in DOD weapon systems over the period 1978 through 1980 and was specifically engaged to provide the following:

1.) Documentation of weapon system end item prices during fiscal years 1978 through 1980

2.) Determination and analysis of causal factors underlying any observed price changes

3.) Assessment of the probable duration of factors which may be causing extraordinary upward price pressures.

Population/Sample. The population of this study is the defense industry. The systems selected for a complete review were mature, stable programs. These programs did not involve any research and development costs and did not have many design or requirement changes. CL justify their sample as follows: "the selection criteria utilized were necessary to maximize comparability of data across systems and across fiscal years."

Summary of Methodology. The researchers' approach to measuring weapon system price changes was accomplished by documenting the contract billing prices by system for each fiscal year in the study. The contract billing prices and other information were collected via a questionnaire/worksheet that was completed by the contractors. This information was then used to construct and analyze the contractors' direct and indirect costs elements. Adjustments were made to the cost data to separate cost increases due to inflation from those caused by quantity increases or decreases and requirement changes.

Results. Table 4 summarizes the CL results. Direct labor averages 10.3 percent of total costs, direct materials 49.3 percent, and overhead comprises 40.4 percent. Labor related expenses make up 66 percent of overhead costs. The results also show that contract billing price rates increased by 9.9 percent for 1978-1979 and 14.9 percent for 1979-1980. Direct material costs account for 49.7 percent of the 1978-1979 increase and 58.9 percent of the 1979-1980 price increase. Overhead costs account for 43.4 percent of the 1978-1979 and 34.2 percent of the 1979-1980 price increases.

The research results also indicate that direct material price increases out-paced inflation in the 1979-1980 period with a rate of growth of 19.2 percent. Overhead costs grew at about the same rate as inflation for both periods. However, the overhead cost categories of "labor fringe benefits" and "utility" charges grew at a faster rate than inflation.

Table 4

Summary of the Coopers and Lybrand Results

	FY1978-79	FY1979-80
A. Price Changes:		
1. Aircraft Price Changes Unadjusted	11.9%	17.6%
2. Aircraft Price Changes Adjusted	9.9%	14.9%
3. Producers Price Index Increase	10.1%	13.4%
4 Gross National Product Deflator Increase	8.6%	9.1%
B. Price Increase by Cost Element		
1. Direct Material	9.9%	19.2%
2. Direct Labor	6.4%	10.6%
3. Overhead and Other	10.5%	13.3%
C. Contribution to Total Price Increase		
1. Direct Material	49.7%	58.9%
2. Direct Labor	6.9%	6.9%
3. Overhead and Other	43.4%	34.2%

	FY 1978	FY 1979	FY 1980
D. Composition of Total Price			
1. Direct Material	49.1%	48.8%	50.1%
2. Direct Labor	10.4%	10.4%	10.0%
3. Overhead and Other	40.4%	40.9%	39.9%

CL concluded that the defense sector will be distinguished from industry as a whole due to economic factors that are unique to it. These factors include rising energy costs (aerospace materials are energy intensive), scarcity of certain critical raw materials, and a limited supply and capacity to produce certain critical parts. They believed these factors will have a significant impact on future weapon system prices (29:5).

The scope of the three studies reviewed in this section are somewhat different. The KA study uses Department of Commerce data from 21 Standard Industrial Classification codes to construct a picture of defense industry cost composition and trends. Martinson has a narrower range of data in his study with 11 specific aircraft plants. CL use an even smaller data base with only five major weapon systems included in the complete review.

While the KA and the CL studies both acknowledge cost growth, they arrive at different cost categories as being primarily responsible for the growth. The KA results indicate that overhead is responsible for most of the cost growth (41.3 percent), and the CL results show that the direct materials category is mostly responsible (54.3 percent) for cost growth. However, all three studies arrive at very similar conclusions about total cost composition. Total cost is 46 to 50 percent direct material, 10 to 16 percent direct labor and 36 to 40 percent overhead. Each study also concludes that labor related costs (indirect labor, fringe benefits, and payroll

taxes) and energy costs comprise the largest proportion of overhead and are primarily responsible for overhead growth.

Summary

Cost and its various components are defined in this chapter. How cost is accounted for and controlled, the parties responsible for controlling costs, and the perception of cost growth and cost composition in the defense industry are also discussed. The last section of this chapter presents empirical studies of cost growth and cost composition in the 1960s and 1970s.

Cost growth existed in the defense industry over the past two decades. Recent manufacturing industry trends (over the past five to ten years) involving technological modernization and automation may be shifting the composition of cost from direct to indirect costs. Also, the intense participation of government in the defense industry, with its emphasis on "high-tech" weapon systems, may be contributing to indirect and total cost growth.

The literature indicates a belief that defense industry costs have been increasing since the 1960s and that the relationship of overhead costs to total costs may also be increasing. The next chapter explains the methodology used to test the study's hypotheses that address these two issues.

III. Methodology

Introduction

The previous chapter provides a review of the literature on cost composition and cost trends in the manufacturing and defense industries. There are assertions made in this literature that costs are increasing in the defense industry and that indirect costs are growing relative to total costs in the manufacturing industry. These assertions form the basis for this study's hypotheses. The first hypothesis is that costs increased in the defense aerospace industry during the period 1980 through 1986. The second hypothesis states that the percentage of overhead costs to total cost increased in the defense aerospace industry during the same period.

This chapter explains the methodology employed to test the study's two hypotheses and is divided into three sections. The first section describes the population and the study's sample. The next section explains the data collection process and data base. The third section explains the data analysis phase which includes the following: (1) the standardization of overhead cost categories; (2) the conversion of costs to constant dollars; (3) the selection of financial measures for use in the statistical analysis; and (4) the statistical analysis which tests the study's two hypotheses. Figure 2 presents a flow diagram of the study's methodology.

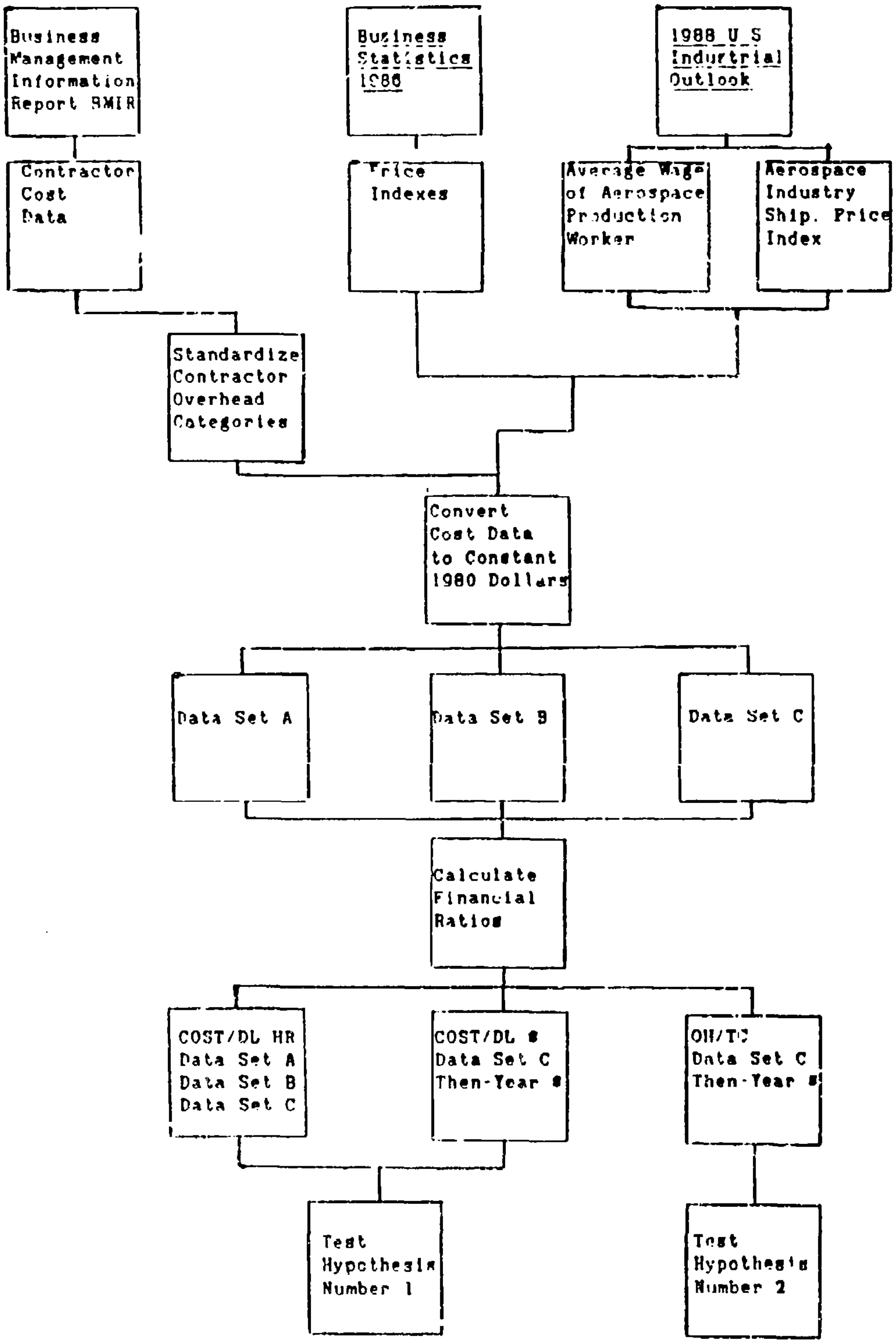

Figure 2. Flow Diagram of Study's Methodology

Population and Sample Size

Population. The population for this study consists of all defense aerospace contractors classified by the following Department of Commerce Standard Industrial Classification (SIC) codes: 3721, Aircraft; 3724, Aircraft Engines and Engine Parts; 3728, Aircraft Equipment; 3761, Guided Missiles and Space Vehicles; 3764, Space Propulsion Units and Parts; and 3769, Space Vehicle Equipment (36:39-1).

Sample Size. The sample is composed of 16 aerospace contractor plants. The plants are under Headquarters Air Force Contract Management Division (HQ AFCMD) cognizance and are located throughout the United States. During the period 1980 to 1986, the sample's total cost averaged 32 percent of aerospace industry sales. Table 5 presents the annual percentage of the sample's total cost to industry sales.

The contractors in the sample were not randomly selected. However, based on the percentages in Table 5 and the fact that the plants produce a broad range of aerospace products such as aircraft, aircraft engines, aircraft equipment, guided missiles and space equipment, it is assumed that the sample is representative of the population.

Data Collection

The cost data were obtained from HQ AFCMD's Business Management Office (BMO). The BMO is responsible for collecting cost data from each plant under Air Force cognizance. The cost data are collected annually via the Business Management Information Report (BMIR), Report

Table 5

Percentage of Sample's Total Cost to
Aerospace Industry Sales

	1980	1981	1982	1983	1984	1985	1986
Costs for Selected Contractors ($ Millions)	24672	25297	25246	26402	31954	34179	40017
Total industry Sales ($ Millions)	69624	72852	86900	92930	104863	110450	110836
% of Costs to Sales	35.4%	34.7%	29.0%	28.4%	30.5%	35.0%	36.1%

Control Symbol (RCS):CMD-TM (A/R) 7801 (AFCMDR 70-1:38). The BMIRs for the period 1980 through 1986 are the source documents for the cost data used in this study.

The Air Force Plant Representative Offices (AFPRO) at the contractors' facilities complete the BMIRs in accordance with AFCMD Regulation 70-1 and additional instructions provided by the BMO. In short, the BMIR is completed by compiling cost data directly from the contractors' cost accounting systems. The result is a record of the contractors' annual costs by cost category--direct labor, direct material, other direct charges, and overhead. The overhead category is further broken down and reported by sub categories.

A number of price indexes were selected to convert the cost data to constant dollars. All but two of the price indexes used in this study were obtained from the Commerce Department's Survey of Current Business 1986 (36). The two exceptions are the Industry Shipments Price Index for the aerospace industry and the figures used to compute the Average Hourly Wage of Aerospace Production Workers Index, both of which were obtained from the International Trade Administration's U S Industrial Outlook 1986 (37). The rationale for using the selected price indexes and a list of the index values are presented later in this chapter (page 38).

Data Analysis

This section explains the (1) standardization of overhead cost categories; (2) conversion of costs to constant dollars;

(3) selection of financial measures for use in the statistical analysis; and (4) the statistical tests for the study's two hypotheses.

Standardization of Overhead Cost Categories.

Before any analysis of the cost figures in the BMIRs can be conducted, the contractors' overhead cost categories must be standardized. The standardization simplifies the data analysis and makes the cost data more comparable between years. HQ AFCMD recognized the need to standardize contractor overhead cost categories reported in the BMIRs. In 1987, the Business Management Office provided instructions to the Air Force Plant Representative Offices (AFPROs) to group contractor overhead costs into nine standardized categories beginning with the 1985 BMIRs (14). These nine categories are listed and explained in Appendix A.

The overhead cost categories are combined into four standard groupings for this study. The study limited the standard overhead cost groupings to four categories because of the difficulty in objectively fitting the contractor overhead cost categories reported in the 1980 through 1984 BMIRs to the standardized overhead categories reported in the 1985 and 1986 BMIRs.

The four standardized overhead cost categories used in this study are as follows:

(1) Labor Related includes all overhead accounts in which the majority of the costs relate to the compensation of indirect employees. This grouping includes, but is not limited to, indirect labor, fringe benefits, payroll taxes, and payroll expenses.

(2) Travel includes all overhead accounts identified as travel expense.

(3) Depreciation, Use, and Occupancy includes all overhead accounts related to the contractor's plant and operating supplies. This grouping includes, but is not limited to, depreciation expense, office supplies, utilities, lease or rent expense, and expendable equipment.

(4) Other includes those overhead accounts that are not included in the above categories. This grouping includes, but is not limited to, computer expenses, hazard insurance, corporate taxes, communication, corporate allocations, miscellaneous transfers, and other expenses.

The result of classifying the BMIR overhead cost categories into the four standardized groupings is contained in Appendix B. The appendix lists each overhead cost category contained in the 1980 through 1986 BMIRs by the appropriate standardized overhead grouping.

Conversion to Constant Dollars. The then-year or actual dollars contained in the BMIRs are deflated by price indexes to obtain a real or constant dollar estimate of the costs in 1980 dollars. Once this adjustment is made, comparison of costs between years can be made.

To mitigate the effect of any bias that may be introduced by the subjective selection of price indexes, three approaches are taken to convert the cost data to constant dollars. The result is the creation of three constant dollar data bases for use in generating the financial measures for the statistical analysis. The constant dollar data bases are labeled Data Sets A, B, and C and are adjusted using the following indexes:

Data Set A: Producer's Price Index (PPI), Industrial Commodities--Transportation Equipment

Data Set B: Industry Shipments Price Index--Aerospace

Data Set C: Adjusted by a composite of the following:

(1) Direct Labor: Average Hourly Wage of Production Workers--Aerospace

(2) Direct Material: Producer Price Index (PPI), Intermediate Material

(3) Other Direct Charges: PPI, Industrial Commodities--Transportation Equipment

(4) Overhead--Labor Related: Employment Cost Index--White Collar Workers

(5) Overhead--Travel: Consumer Price Index (CPI), Public Transportation

(6) Overhead--Depreciation Use, and Other: Average of:

(a) PPI, Industrial Commodities--Equipment and Machinery

(b) PPI, Industrial Commodities--Capital Equip

(c) CPI, Fuel And Utilities--Piped Gas and Electricity

(7) Overhead--Other: PPI, Industrial Commodities--Transportation Equipment

The rationale for selecting the price indexes for each data set is presented in Appendix C. Table 6 lists the price index values for each year and data set with 1980 as the base year. The table lists these index values in the same format as above For example, "Data Set C (1)" lists the price index values for direct labor. Appendix D presents the sample's direct and indirect costs in then-year and constant dollars (Data Sets A, B, and C) for years 1980 through 1986.

Table 6

Price Index Values for Data Sets A, B, and C
(Base Year = 1980)

Year		1980	1981	1982	1983	1984	1985	1986
Data Set A		100	113.7	120.6	124.0	126.9	130.2	133.3
Data Set B		100	112.6	124.5	130.6	136.0	137.4	139.5
Data Set C	(1)	100	113.0	123.4	132.1	133.7	140.2	144.8
	(2)	100	109.2	110.7	111.4	114.2	113.7	109.7
	(3)	100	113.7	120.6	124.0	126.9	130.2	133.3
	(4)	100	108.3	116.7	124.5	132.3	139.0	145.4
	(5)	100	112.1	116.7	119.5	124.8	128.1	129.8
	(6a)	100	109.7	116.3	119.4	122.2	124.6	126.5
	(6b)	100	110.2	116.5	119.8	122.6	125.3	127.7
	(6c)	100	114.6	130.5	142.0	147.5	150.0	148.0
	(7)	100	113.7	120.6	124.0	126.9	130.2	133.3

Financial Measures. The financial measures explained in the following paragraphs are used to test the study's two hypotheses. The financial measures consist of (1) an activity base used to represent industry output; and (2) financial ratios used as dependent variables in the statistical tests.

Activity Base. An activity base that measures industry output must be selected to provide a relative measure of cost growth during the period 1980 to 1986. This activity base is necessary in order to identify cost growth that is not associated with sales growth. Figure 3 is a graph of the sample's total costs and total direct labor, direct material, other direct, and overhead costs in then-year dollars for 1980 through 1986. Figure 4 is the same graph in constant dollars (Data Set C). It is impossible to interpret from either graph the portion of cost growth driven by increased sales from that portion driven by other factors. To help eliminate this problem, an activity base that allows costs to be expressed in a cost per unit measure is required.

Units produced probably provides the most accurate measure of industry output. However, such a measure is not readily available for this study. Instead, two other measures are used as activity bases to gauge industry output. These measures are direct labor hours and direct labor dollars. The use of these activity bases as surrogates for output is a legitimate option because, in general, as output increases or decreases so does direct labor (4:122).

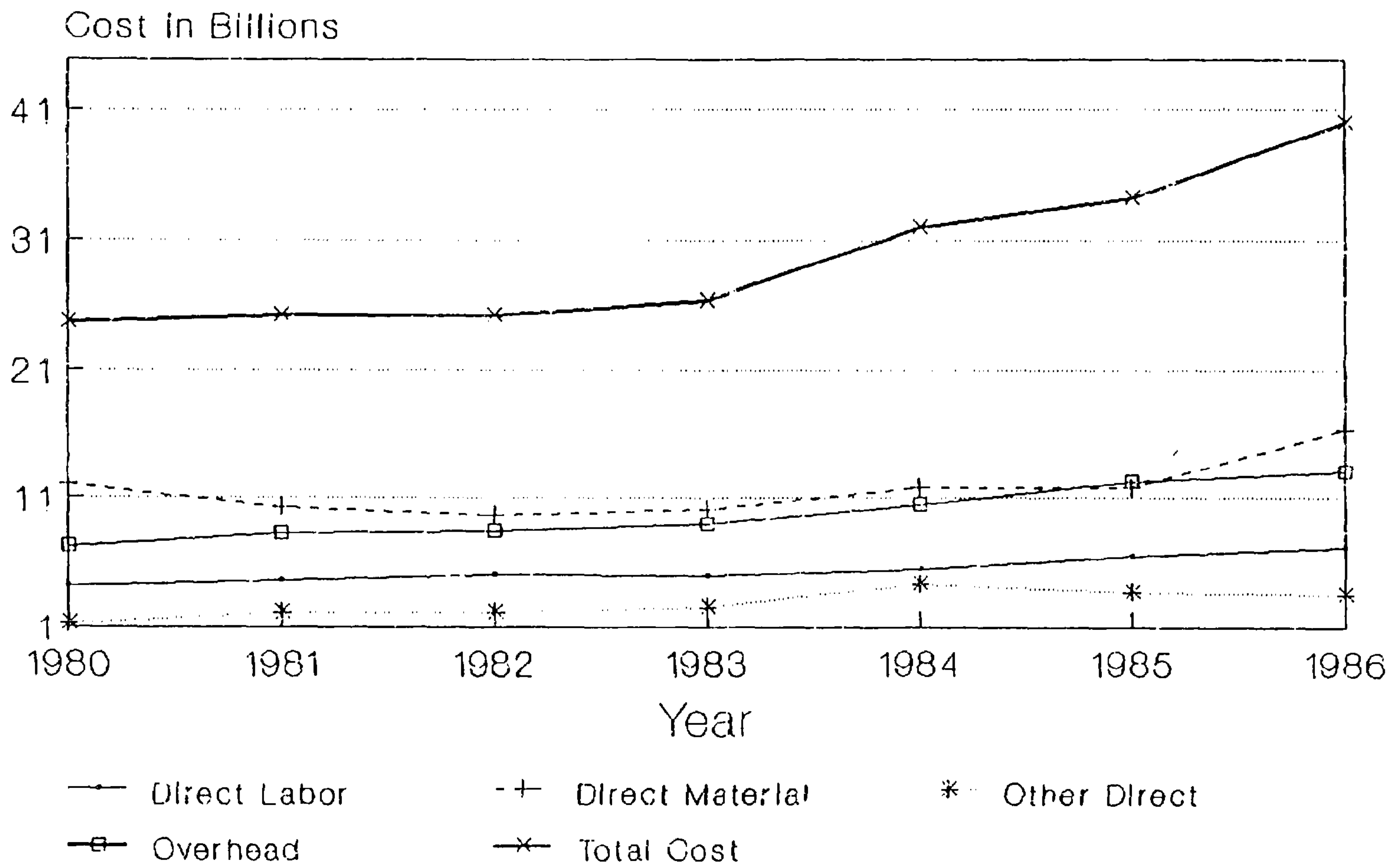

Figure 3. Sample's Total Cost in Then-Year Dollars

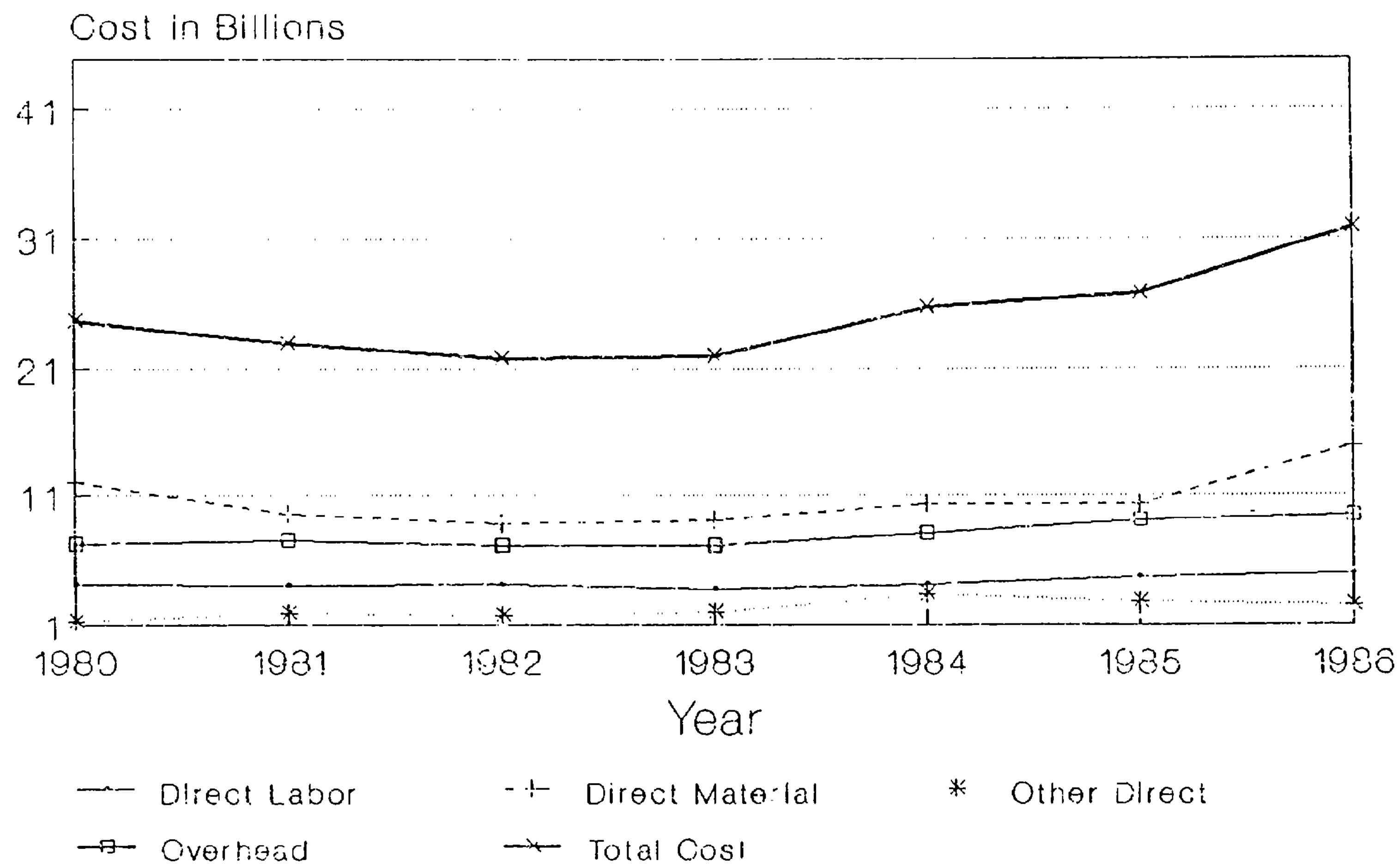

Figure 4. Sample's Total Costs in Constant Dollars, Data Set C

The direct labor hours are computed for each contractor by dividing the contractor's direct labor costs by the average hourly wage of aerospace production workers. The average hourly wage data are contained in U S Industrial Outlook 1988 (37:39-2,39-2).

Financial Ratios. Financial ratios are required to serve as dependent variables in the statistical tests. These ratios measure certain financial characteristics of the sample.

The ratios of Cost Per Direct Labor Hour (Cost/DL Hr) and Cost Per Direct Labor Dollar (Cost/DL $) are used to test hypothesis number one. It is assumed that increases in these ratios indicate that costs in the industry have increased, while decreases in the ratios indicate the opposite. Both measures are used in the test of hypothesis number one to see if like results are obtained. Like results will help substantiate the conclusions assuming that each ratio accurately measures industry cost growth for the seven year period.

The ratio of Overhead Costs to Total Costs (OH/TC) is used to test hypothesis number two. It is assumed that an increase in this ratio indicates that the percentage of overhead costs to total cost has increased and a decrease in the ratio indicates the opposite.

All three financial ratios are expressed in constant dollars for use in the hypothesis tests. Table 7 provides a summary of the financial ratios and how they will be used in

Table 7

Financial Ratios Used as Dependent Variables in Statistical Analysis

	Hypothesis No. 1	Hypothesis No. 2
Data Set	Dependent Variable	Dependent Variable
A	Cost per DL Hour	
B	Cost per DL Hour	
C	Cost per DL Hour	
Then-Year $	Cost per DL Dollar	
C	Cost per DL Dollar	
Then-Year $		Overhead/Total Cost
C		Overhead/Total Cost

the hypothesis tests. Appendix E provides a list of the financial ratio values by contractor and year for Data Sets A, B, and C and the Then-Year dollars Data Set.

It should be noted that a ratio of a cost to a cost is computed only in then-year dollars and for Data Set C. Data sets A and B are each adjusted to constant dollars using one price index and, therefore, the cost to cost ratio does not change. For example, the ratio of overhead costs to total cost is the same for the Then-Year Dollars Data Set, Data Set A, and Data Set B.

Statistical Analysis. Statistical analysis is used in this study because the available cost data are but a sample of the defense aerospace industry population. By applying statistical techniques, a conclusion may be drawn about the population from the sample information (24:5).

The statistical technique chosen for this study is regression analysis. A line of best fit is computed through the data points by a method called 'ordinary least squares' (OLS). OLS is a statistical tool that is used to determine the existence of a relationship between two or more quantitative variables ((25:23).

In this study, the relation between the independent variable 'year' and the dependent variable 'financial ratio' (listed in Table 7) is determined. The general regression model is:

$$y = a + bx + e \qquad (3)$$

where

y = the dependent variable
a = the Y intercept
b = the slope of the regression line
x = the independent variable
e = the random error term

The study's regression model is:

$$\text{Financial Ratio} = a + b(\text{Year}) + e \tag{4}$$

The financial ratios for each contractor are used as the dependent variables in the regression analysis. This yields 16 observations for each year or a total of 112 observations (16 contractors * 7 years) for the sample.

This statistical analysis tests whether the slope of the fitted regression line is significantly greater than zero. If the test concludes that the slope is significantly greater than zero, then the financial ratio has increased during the period 1980 to 1986.

As an aid in the following discussion on the hypothesis tests, the reader is referred to Table 8 on page 48. The statistical tests for hypotheses one and two are the same. The null (Ho) and alternative (Ha) hypotheses for each test are stated as follows:

Ho: The slope of the regression line (b) equals zero

Ha: The slope of the regression line is greater than zero

Table 8

Summary of Hypothesis Tests

	Hypothesis No. 1	Hypothesis No. 2
Null and Alternative Hypotheses	Ho: b = 0 Ha: b > 0	Ho: b = 0 Ha: b > 0
Regression Models		
Data Set A	Cost/DL Hour = a + b(Year)	
Data Set B	Cost/DL Hour = a + b(Year)	
Data Set C	Cost/DL Hour = a + b(Year)	
Then Year Dollars	Cost/DL Dollar = a + b(Year)	OH Costs/Total Cost = a + b(Year)
Data Set C	Cost/DL Dollar = b + b(Year)	OH Costs/Total Cost = a + b(Year)
Level of Significance	5.0%	5.0%
Decision Rule	If the calculated t value $\leq$ 1.66, then Ho cannot be rejected. If the calculated t value > 1.66, then reject Ho.	If the calculated t value $\leq$ 1.66, then Ho cannot be rejected. If the calculated t value > 1.56, then reject Ho.
Conclusions	If Ho is rejected, then Hypothesis Number 1 is true. If Ho is not rejected, then Hypothesis Number 1 is not true.	If Ho is rejected, then Hypothesis Number 2 is true. If Ho is not rejected, then Hypothesis Number 1 is not true.

According to Hamburg, selecting the level of significance of the test depends on the risk the researcher is willing to accept of rejecting the null hypothesis when it is true. "Significance levels such as 0.05 and 0.01 are very frequently used in classical hypothesis testing" (15:265). For this study, the significance level is set at 0.05.

The critical t value is 1.66 for this one-tailed hypothesis test, with 110 degrees of freedom (112 observations less two parameter estimates). The critical t value is obtained from a table of percentiles of the t distribution ((25:518). The critical t value is compared to the calculated t value which is computed as follows:

$$\frac{b - B}{Sx} \tag{5}$$

where

b = the slope of the sample regression line.
B = the true slope of the population regression line hypothesized to be zero for this test.
Sx = the estimated standard error of b.

If the calculated t value is greater than the critical t value, then it is assumed that the slope of the population regression line is greater than zero.

Using the information in this and the previous paragraph, the decision rule for both hypothesis tests is stated as follows:

If the calculated t value $\leq$ 1.66, then Ho cannot be rejected.

If the calculated t value > 1.66, then reject Ho.

Rejection of the null hypothesis infers that the slope of the population regression line is greater than zero and that the financial ratio has increased during the period 1980 through 1986. Such a result would support hypotheses one and two. However, if the null hypothesis cannot be rejected, it is inferred that the slope of the population's regression line is zero and the study's two hypotheses would not be supported by this statistical analysis.

Two assumptions of regression analysis are that the residuals or error terms are normally distributed and independent of one another. Therefore, the sample data are tested for normality and the existence of autocorrelation.

The Kolmogorov-Smirnov (K-S) "goodness-of-fit" test is employed to test "the null hypothesis that the sample and theoretical distributions are equal" (24:458). For this study, the theoretical distribution is the normal distribution. The following test statistic, denoted as "D" is computed.

$$D = \text{maximum } |F - S| \tag{6}$$

where

F = The cumulative relative frequencies of the theoretical distribution.

S = The comparable relative frequencies of the sample data.

The computed D value is compared to the critical D value obtained from a table of K-S critical values for one sample tests. For this test, the number of observations is equal to 112 (16 contractors * 7 years) and the level of significance is 0.01. Therefore, the critical D value is equal to:

$$D \text{ critical} = \frac{1.63}{\sqrt{112}} = 0.1540205 \qquad (7)$$

The null hypothesis (Ho) and accompanying decision rule are as follows:

Ho: The sample and theoretical distributions are equal.

Ha: The sample and theoretical distributions are not equal.

Decision Rule: If the computed D value < the critical D value, accept Ho and conclude that the sample distribution represents a normal distribution.

"The Durbin-Watson test provides the standard test for autocorrelation" (24:555). The test is accomplished by computing the following test statistic denoted as "D".

$$D = \frac{\sum_{a=2}^{n} (ea - eb)^2}{\sum_{a=1}^{n} (e)^2_a} \qquad (8)$$

Where

e = the residuals of the regression model
a = the sequential position of a particular e
b = a - 1
n = the number of observations.

Upper (du) and lower (dl) bounds are obtained from a table of Durbin-Watson test bounds ((25:531) with the level of significance set at 5% and a sample size of 112. The test for positive one period autocorrelation is:

Ho: $p = 0$
Ha: $p > 0$

If $D > 1.56$ (du), then Ho cannot be rejected

If $D < 1.52$ (dl), then reject Ho and conclude that the error terms are positively correlated

If $1.52 \leq D \leq 1.56$, the test is inconclusive

The test for negative one period autocorrelation is:

Ho: $p = 0$
Ha: $p < 0$

If $(4-D) > 1.56$, then Ho cannot be rejected

If $(4-D) < 1.52$, then reject Ho and conclude that the error terms are negatively correlated

If $1.52 \leq (4-D) \leq 1.56$, The test is inconclusive

where

p = autocorrelation parameter
du = The upper Durbin-Watson test bound
dl = The lower Durbin-Watson test bound

Summary

This chapter explains the methodology employed to test the study's two hypotheses. The population for the study is the defense aerospace industry. The sample is comprised of 16 aerospace contractor plants and the BMIRs from these plants serve as the source documents for the cost data. The contractor costs are discounted to constant dollars from which three financial ratios are computed. These ratios are used in the hypothesis tests to determine whether costs have increased in the defense aerospace industry from 1980 to 1986; and to determine whether the percentage of overhead costs to total cost increased in the industry over the same period.

The next chapter contains the results of the hypothesis tests, presents descriptive statistics that help to further describe the sample's cost composition and trends, and includes the corollary findings of this study.

IV. Data Analysis and Findings

Introduction

The previous chapter describes the methodology used to test the study's two hypotheses. This chapter contains the primary results of the data and statistical analysis and is presented in four sections. The first section presents and explains the results of the hypothesis tests. Next, the outcomes of the Kolmogorov-Smirnov 'goodness-of-fit' test for normality and the Durbin-Watson test for autocorrelation are presented. The third section provides some descriptive statistics which further describe the sample's cost composition and trends. Finally, the fourth section presents the corollary findings of this study.

Hypothesis Tests

The primary results of testing the study's two hypotheses are presented in this section. The parameter estimates for each test are discussed in the following paragraphs. In particular, the parameter estimates for the independent variable are examined since these estimates provide statistics about the slope (b) of the regression line.

Hypothesis Number One. **Costs increased in the defense aerospace industry during the period 1980 through 1986.**

To test the first hypothesis, the dependent variables of Cost Per Direct Labor Hour (Cost/DL Hr) and Cost Per Direct Labor Dollar (Cost/DL $) are regressed against the independent

variable 'year'. The use of two dependent variables yield the following two regression models:

$$\text{Cost/DL Hr} = a + b(\text{Year}) + e \tag{9}$$

$$\text{Cost/DL \$} = a + b(\text{Year}) + e \tag{10}$$

Parameter estimates are calculated for each model. Table 9 contains the statistical results when Cost/DL Hr is used as the dependent variable. The table lists the parameter estimates (coefficients, standard errors, and t values) for the intercept and independent variable 'year' for the three Constant Dollar Data Sets. For each data set, the computed t value for the variable 'year' is less than the critical t-value of 1.66 when tested at the 5% level of significance. The largest t value is 1.29 for Data Set C and the smallest t value is 0.540 for Data Set B. Based on the decision rule defined on page 50, the null hypothesis cannot be rejected.

Figures 5, 6, and 7 present scatter plots of the dependent variable Cost/DL Hour for Constant Dollar Data Sets A, B, and C, respectively. The X axis plots the years 1980 through 1986 with 16 tick marks for each year representing the 16 contractors. A trend line is also fitted through the data points which provides a visual representation of the significance of the slope of the regression line.

Table 10 provides the statistical results when Cost/DL $ is used as the dependent variable. This table lists the parameter estimates for the intercept and the independent

Table 9

Summary of Statistical Results--Hypothesis Number One, Cost/DL Hour Ratio

Constant Dollars, Data Set A

Parameter Estimates:

Variable	Coefficient	Std. Error	t Value
Intercept	-2251.84681	2058.01399	-1.09
Year	1.16435	1.03783	1.12

Constant Dollars, Data Set B

Parameter Estimates:

Variable	Coefficient	Std. Error	t Value
Intercept	-1025.43842	1984.38988	-0.52
Year	0.54488	1.00007	0.54

Constant Dollars, Data Set C

Parameter Estimates:

Variable	Coefficient	Std. Error	t Value
Intercept	-2731.81467	2170.67108	-1.26
Year	1.40712	1.09464	1.29

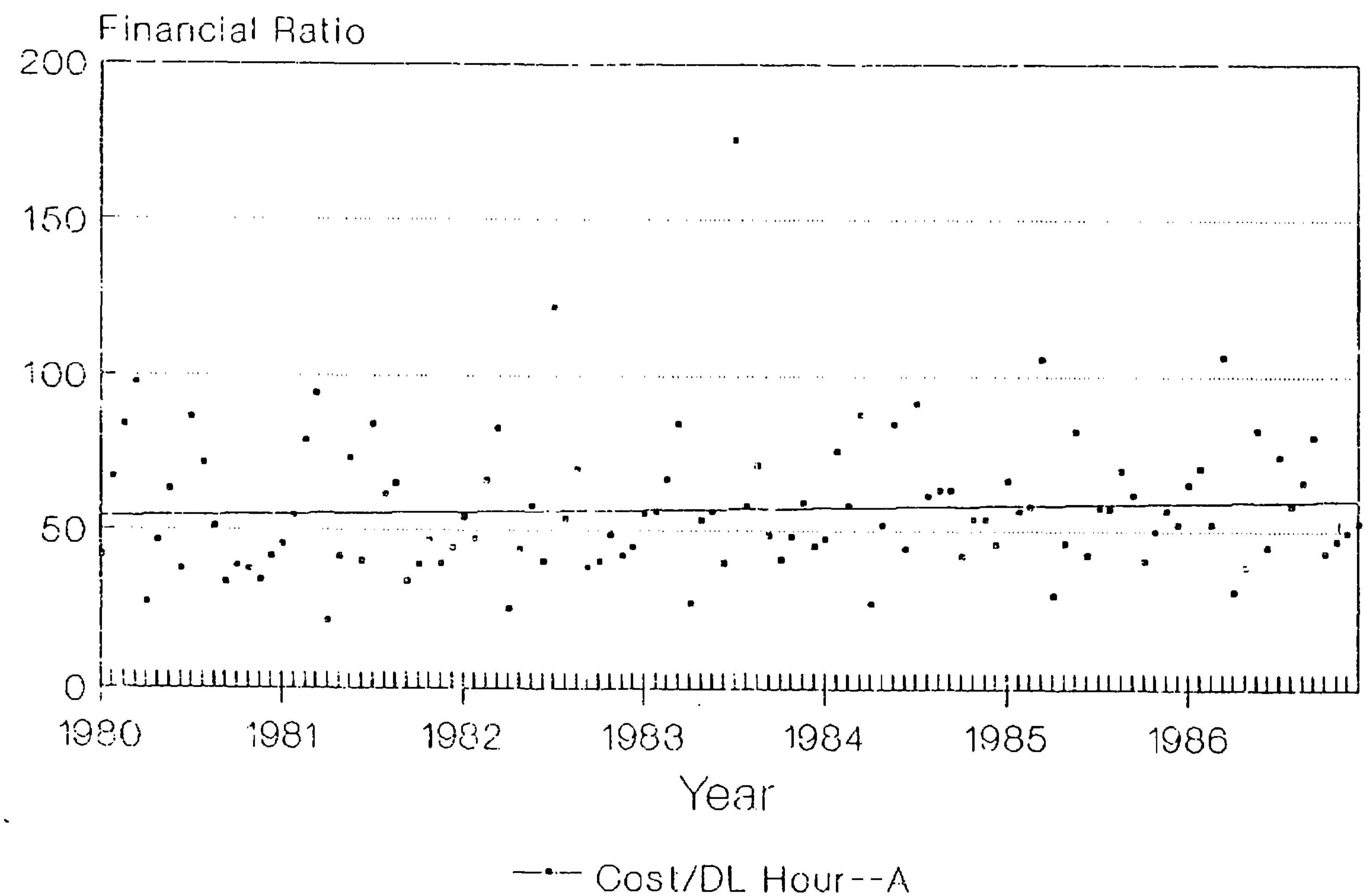

Figure 5. Scatter Plot of Cost/DL Hour Ratio, Data Set A

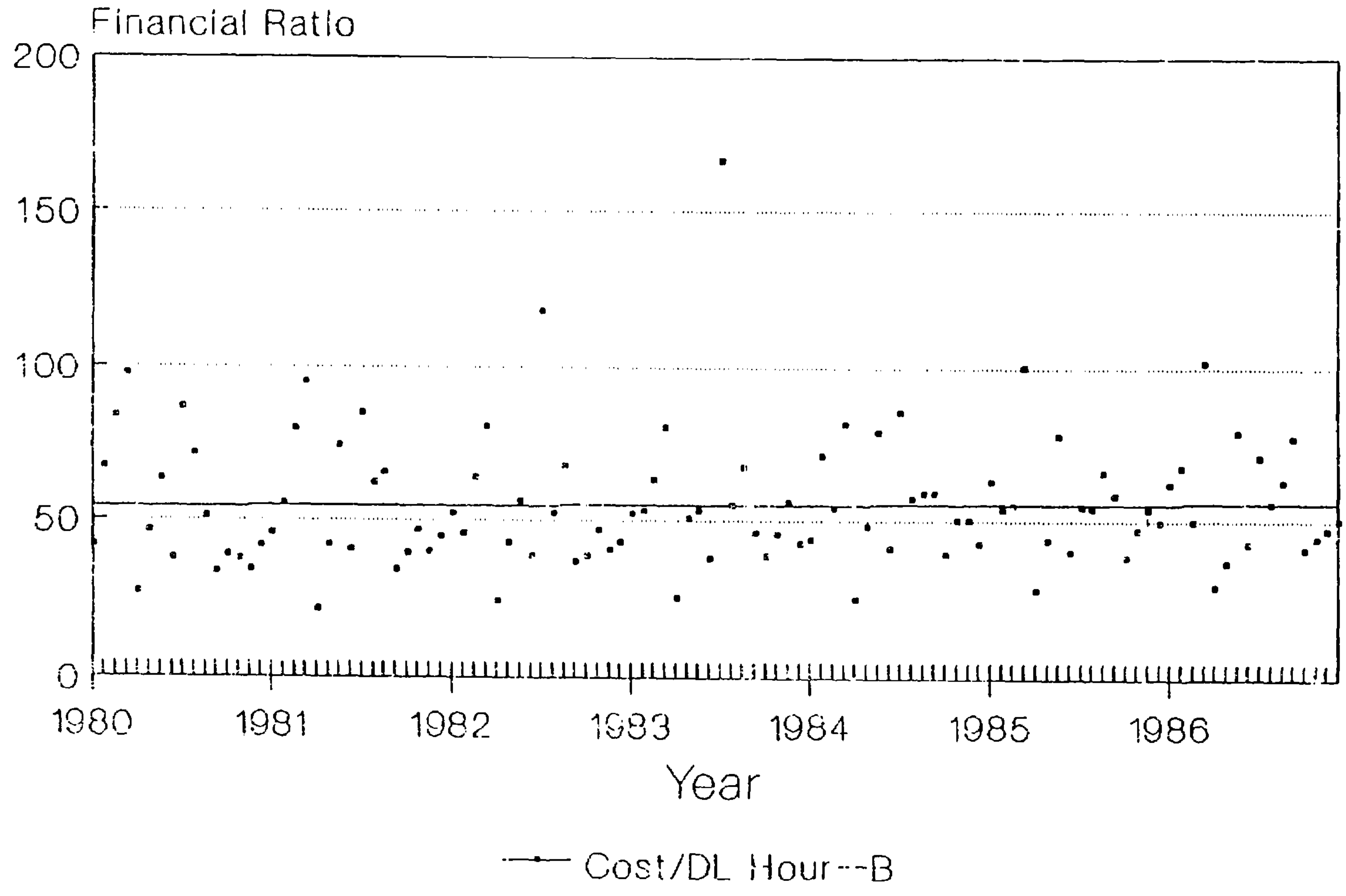

Figure 6. Scatter Plot of Cost/DL Hour Ratio, Data Set B

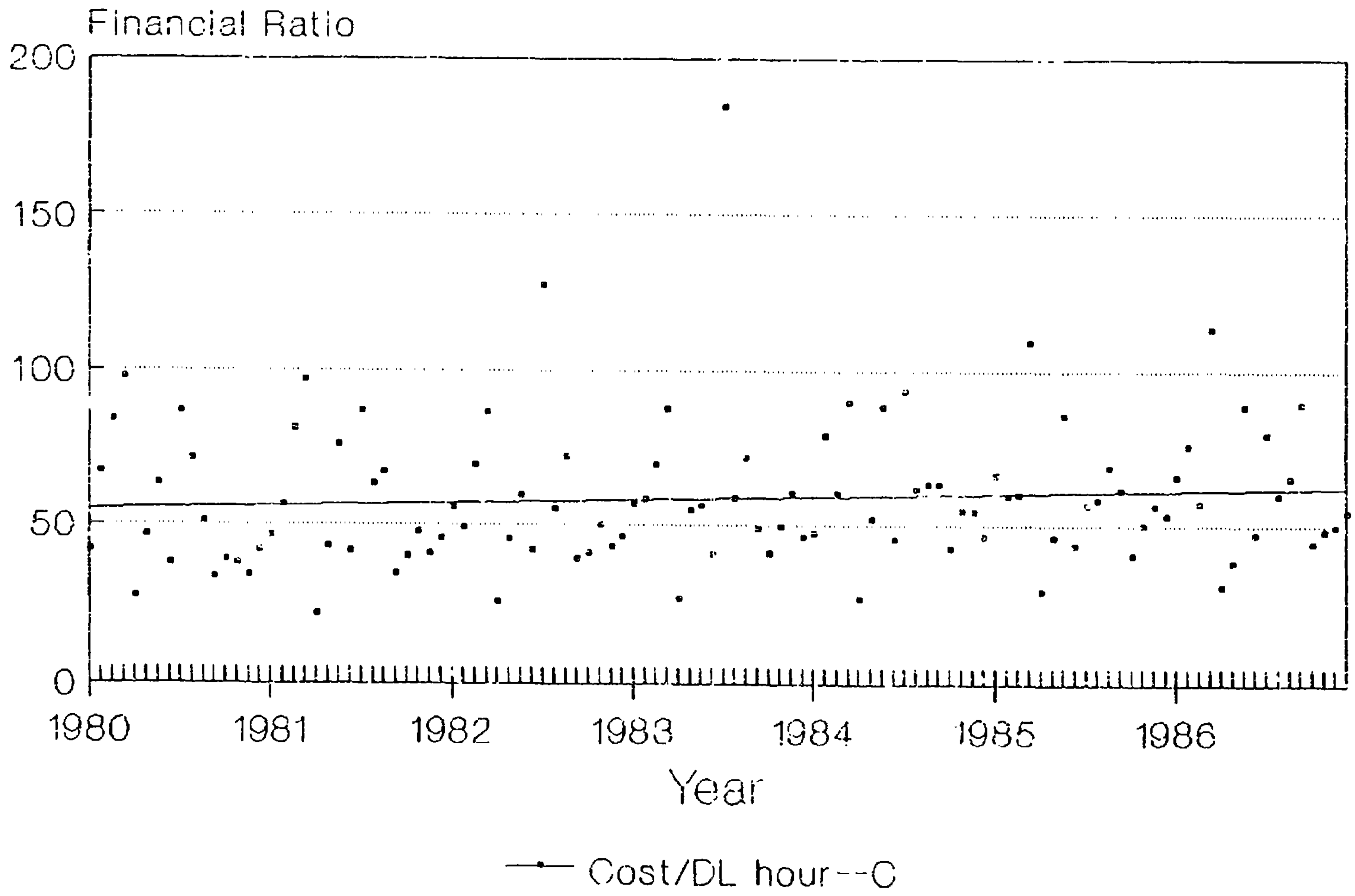

Figure 7. Scatter plot of Cost/DL Hour Ratio, Data Set C

Table 10

Summary of Statistical Results--Hypothesis Number One, Cost/DL # Ratio

Constant Dollars, Data Set C

Parameter Estimates:

Variable	Coefficient	Std. Error	t Value
Intercept	-275.60625	219.22173	-1.26
Year	0.14196	0.11085	1.28

Then Year Dollars

Parameter Estimates:

Variable	Coefficient	Std. Error	t Value
Intercept	-48.47661	199.08602	-0.24
Year	0.02723	0.10040	0.27

variable 'year' in then-year dollars and for Data Set C. As explained on page 45, Cost/DL # is a cost to cost ratio and, therefore, has the same value when computed in then-year dollars as that computed with Data Sets A and B.

For then-year dollars and Data Set C, the t value for the variable 'year' is less than the critical t value of 1.66. Data Set C has the higher t value of 1.28; the Then-Year Dollars Data Set has a t value of 0.27. Again, the null hypothesis cannot be rejected.

Figures 8 and 9 present scatter plots of the dependent variable Cost/DL # for Constant Dollar Data Set C and the Then-Year Dollars Data Set respectively. A trend line is fitted through the data points which provides a visual representation of the significance of the slope of the regression line.

Both the Cost/DL Hr and Cost/DL # variables yield results that infer that the slope of the population regression line is zero. This indicates that the financial ratios Cost/DL Hour and Cost/DL # did not increase during the period 1980 to 1986. Since these ratios are used by the study to measure cost growth, the study's first hypothesis is not supported by the statistical analysis.

It is also interesting to note that the Constant Dollar Data Sets A, B and C yield the same results; that is, the null hypothesis cannot be rejected. The fact that the Constant Dollar Data Sets do not provide conflicting outcomes helps substantiate the results of this hypothesis test.

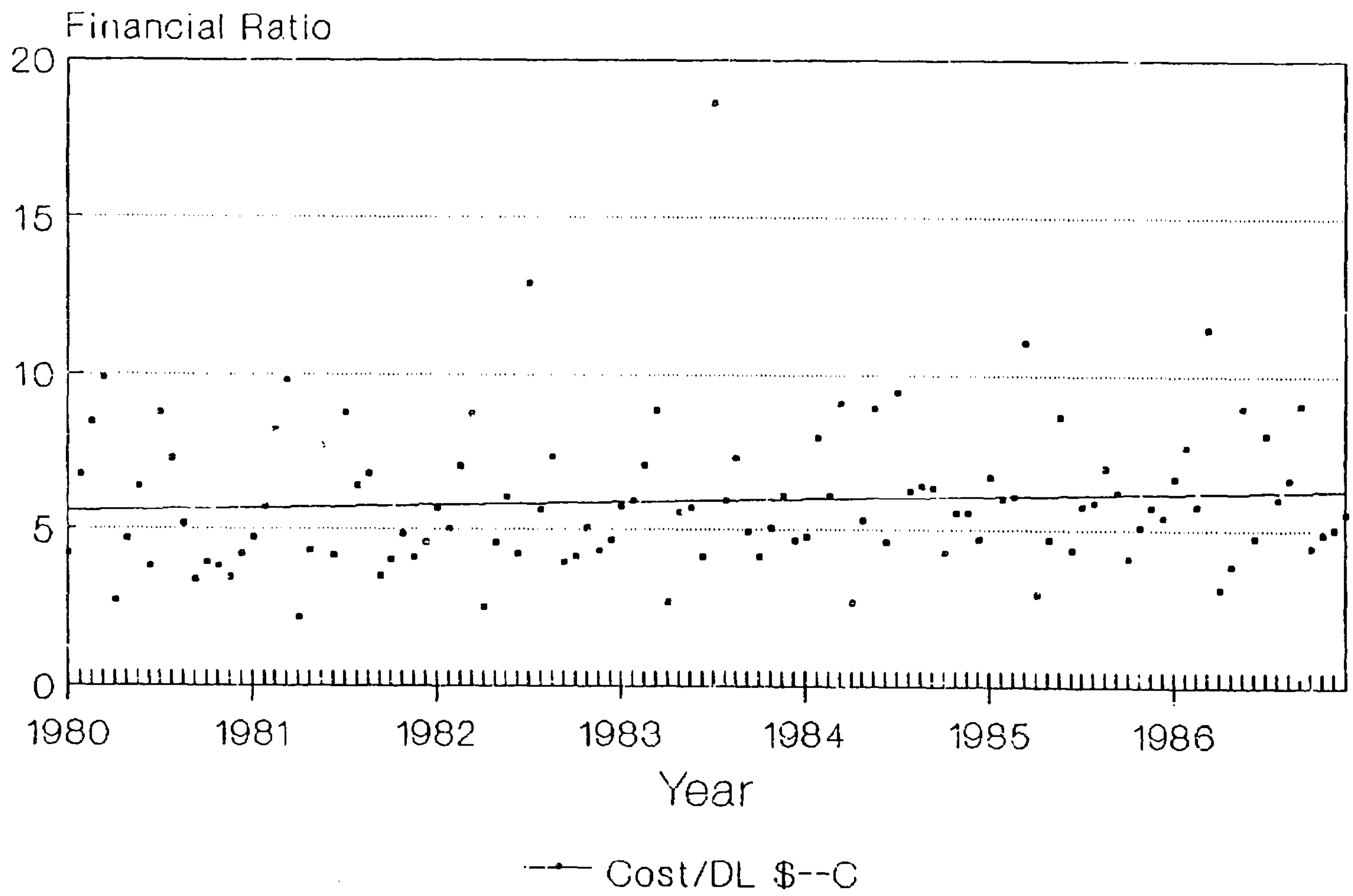

Figure 8. Scatter Plot of Cost/DL $ Ratic, Data Set C

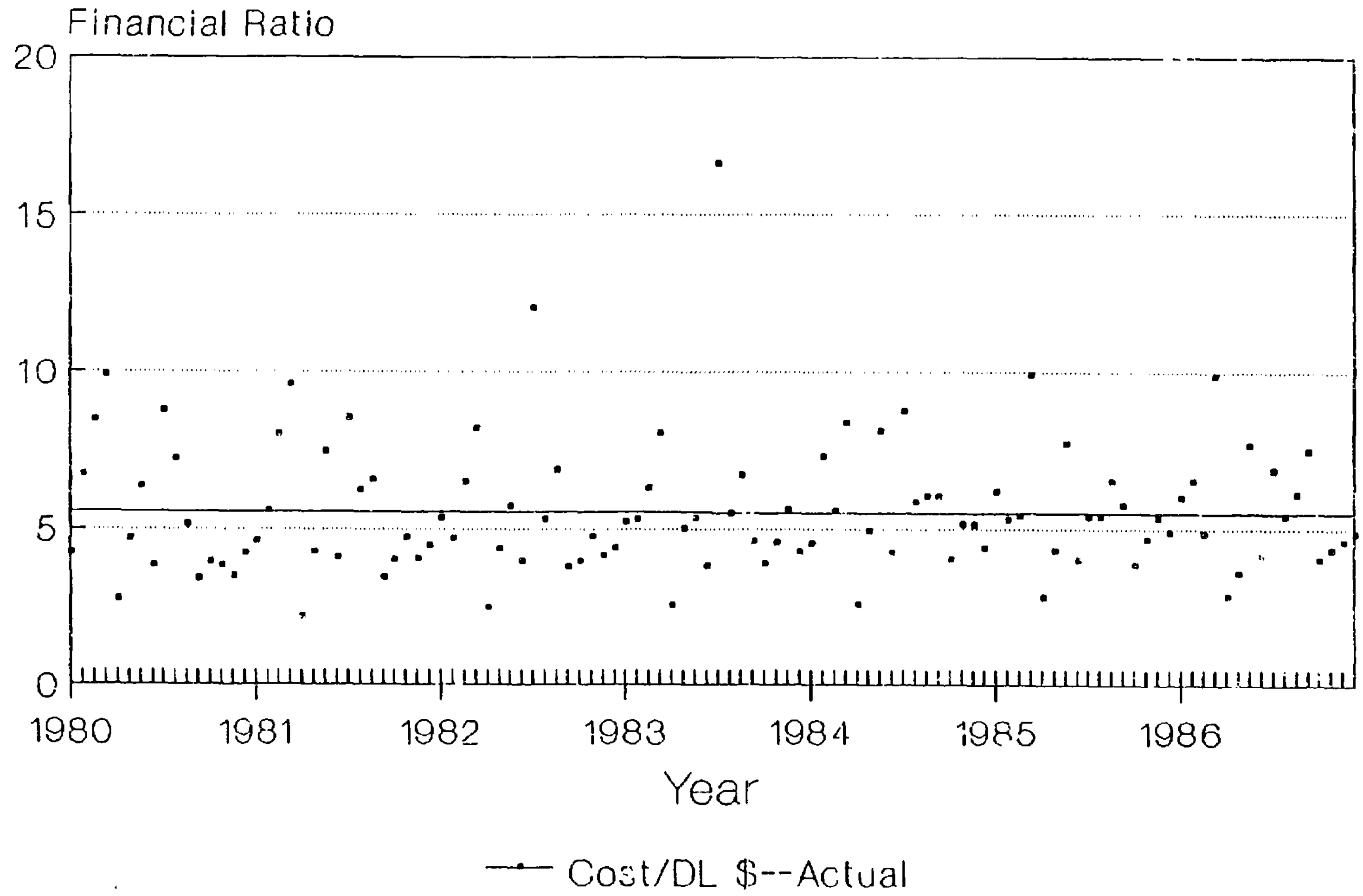

Figure 9. Scatter Plot of Cost/DL $ Ratio, Then-Year Dollars

Hypothesis Number Two. **The percentage of overhead costs to total cost increased in the defense aerospace industry during the period 1980 through 1986.**

To test the first hypothesis, the dependent variable OH/TC is regressed against the independent variable 'year'. The regression model is as follows:

$$OH/TC = a + b(Year) + e \qquad (11)$$

Table 11 contains the statistical results when OH/TC is used as the dependent variable. The table lists the parameter estimates for the intercept and the independent variable 'year' in then-year dollars and for Data Set C. For then-year dollars and Data Set C, the t value for the variable 'year' is less than the critical t value of 1.66. Data Set C has the higher t value of -0.28, while the then-year dollars' t value is -1.37. Based on the decision rule for this hypothesis test, on page 50, the null hypothesis cannot be rejected.

Figures 10 and 11 present scatter plots of the dependent variable OH/TC for Constant Dollar Data Set C and the Then-Year Dollars Data Set. A trend line is fitted through the data points which provides a visual representation of the significance of the slope of the regression line.

Table 11

Summary of Statistical Results--Hypothesis Number Two, OH/TC Ratio

Constant Dollars, Data Set C

Parameter Estimates:

Variable	Coefficient	Std. Error	t Value
Intercept	3.08809	9.67902	0.32
Year	-0.00137	0.00488	-0.28

Then Year Dollars

Parameter Estimates:

Variable	Coefficient	Std. Error	t Value
Intercept	14.05485	10.01793	1.40
Year	-0.00689	0.00305	-1.37

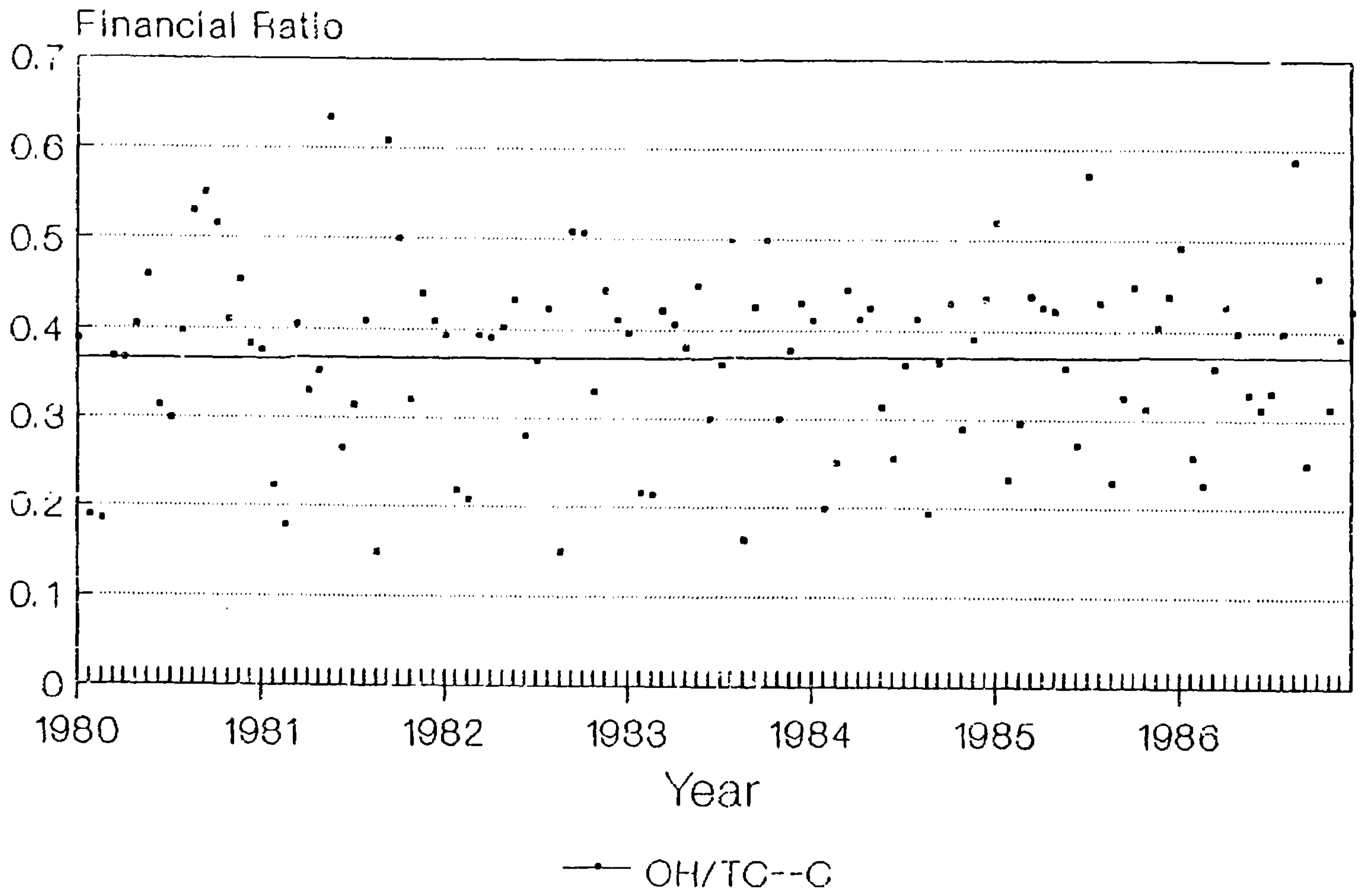

Figure 10. Scatter Plot of OH/TC Ratio, Data Set C

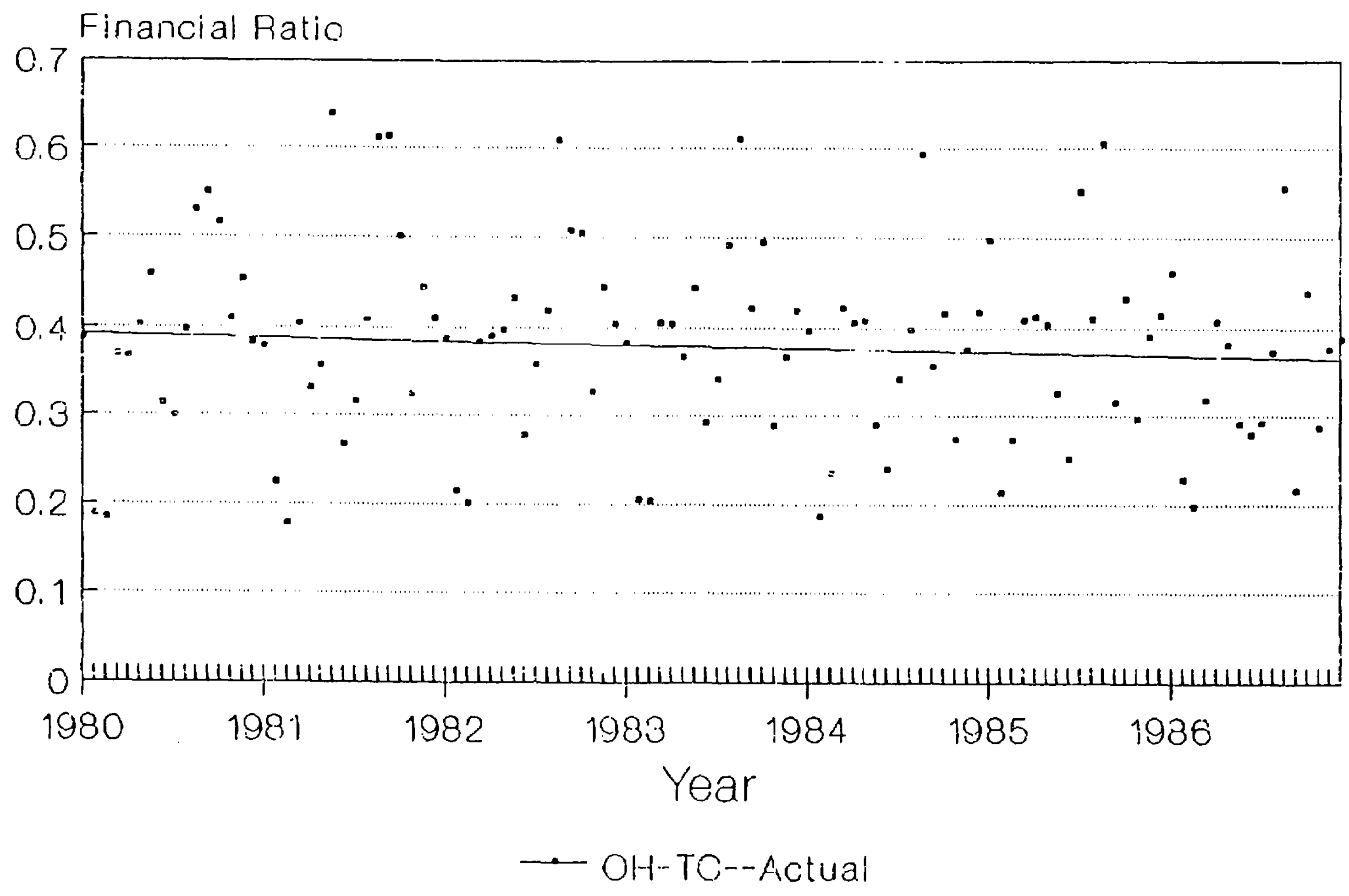

Figure 11. Scatter Plot of OH/TC Ratio, Then-Year Dollars

The results infer that the slope of the population regression line is zero. This indicates that the ratio of Overhead Costs to Total Cost did not increase during the period 1980 to 1986. Therefore, the study's second hypothesis is not supported by the statistical analysis.

Goodness-of-Fit and Autocorrelation Test Results

The computed D values for the K-S 'goodness-of-fit' test for normality and the Durbin-Watson test for autocorrelation are presented in Table 12.

All of the K-S computed D values are less than the critical D value of 0.1540205. Based on the decision rule (page 51), these results indicate that the cost data are normally distributed. In addition, the Durbin-Watson computed D values for positive and negative autocorrelation are larger than the critical D value of 1.56. Based on the decision rule (page 52), it is assumed that no serious autocorrelation exists in the regression models.

Descriptive Statistics.

Table 13 provides the sample's average, high, and low, values for the Cost/DL Hour ratio for each year in then-year dollars and for Constant Dollar Data Sets A, B, and C. The average is calculated by dividing the sample's annual total costs by total annual direct labor hours.

Figure 12 contains a graphical representation of the data in Table 13. The bold line charts the cost per direct labor hour in then year dollars and indicates a definite upward

Table 12

Kolmogrov-Smirnov and Durbin-Watson Computed D Values

Models	K-S	D-W D	D-W 4 - D
Cost/DL Hr = $b_0 + b_1$(Year) (Data Set A)	0.127525	2.254	1.746
Cost/DL HR = $b_0 + b_1$(Year) (Data Set B)	0.138284	2.245	1.755
Cost/DL Hr = $b_0 + b_1$(Year) (Data Set C)	0.129008	2.260	1.740
Cost/DL \$ = $b_0 + b_1$(Year) (Then-Year Dollars)	0.111763	2.242	1.758
Cost/DL \$ = $b_0 + b_1$(Year) (Data Set C)	0.129146	2.260	1.740
OH/TC = $b_0 + b_1$(Year) (Then-Year Dollars)	0.138094	2.037	1.963
OH/TC = $b_0 + b_1$(Year) (Data Set C)	0.098307	1.579	2.421

Table 13

Descriptive Statistics
Cost/DL Hour Ratio

Cost Per Direct Labor Hour--Constant Dollars, Data Set A

	1980	1981	1982	1983	1984	1985	1986
AVERAGE	59.25	54.39	50.79	56.81	61.32	55.82	60.09
HIGH	97.47	94.02	121.88	175.12	91.14	105.44	106.16
LOW	26.80	21.10	24.65	26.56	26.72	29.46	30.46

Cost Per Direct Labor Hour--Constant Dollars, Data Set B

	1980	1981	1982	1983	1984	1985	1986
AVERAGE	59.25	54.92	49.20	53.94	57.21	52.90	57.42
HIGH	97.47	94.94	118.06	166.27	85.04	99.92	101.44
LOW	26.80	21.30	23.88	25.22	24.93	27.92	29.11

Cost Per Direct Labor Hour--Constant Dollars, Data Set C

	1980	1981	1982	1983	1984	1985	1986
AVERAGE	59.25	55.59	52.66	58.52	62.72	57.05	63.62
HIGH	97.47	96.88	127.41	183.91	93.27	109.19	113.77
LOW	26.80	21.51	25.00	26.44	26.49	29.07	40.60

Cost Per Direct Labor Hour--Then Year Dollars

	1980	1981	1982	1983	1984	1985	1986
AVERAGE	59.25	61.64	61.26	70.45	77.61	72.86	80.10
HIGH	97.47	106.91	146.99	217.15	115.66	137.29	141.51
LOW	26.80	23.99	29.73	32.93	33.91	38.36	40.60

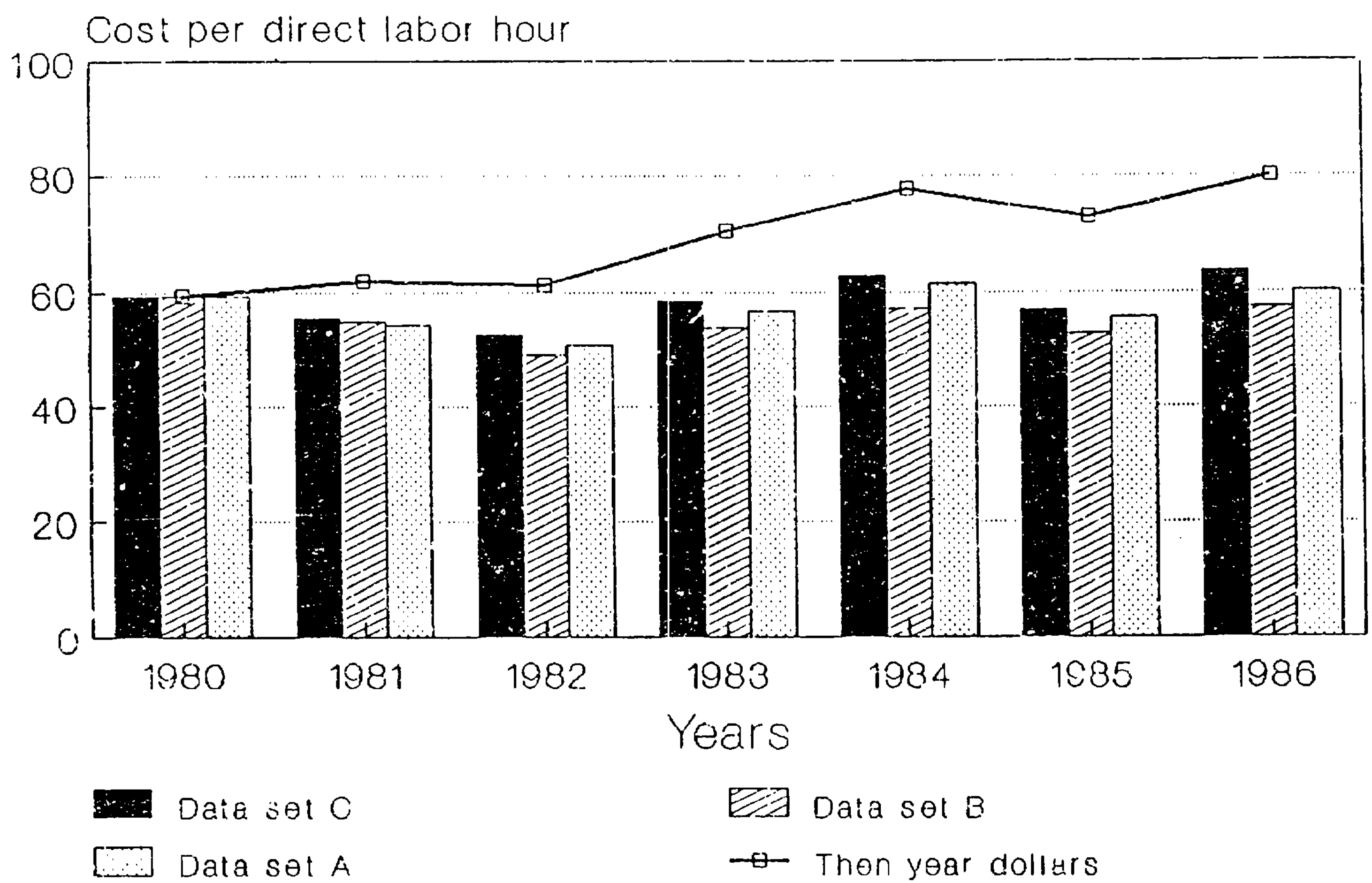

Figure 12. Graph of Cost/DL Hour Ratio Annual Averages

trend for the period. The bars represent each of the Constant Dollar Data Sets. As can be seen from the graph, costs remained rather stable, relative to direct labor hours, when adjusted to constant dollars.

Table 14 presents the sample's average, high, and low values for the Cost/DL # ratio for each year in then-year dollars and for Constant Dollar Data Set C. The data in Table 14 basically support those in Table 13. That is, that no clear increasing trend exists in the data.

Table 15 provides the composition of total cost by each of its major categories--direct labor, direct material, other direct charges, and overhead for each year. These figures are given for Constant Dollar Data Set C and the Then-Year Dollars Data Set. The "direct material" category has the largest share of total costs averaging 42.41% and 39.72% for the Constant Dollar and Then-Year Dollars Data Sets respectively. "Overhead" costs comprise the second largest portion of total costs averaging 31.69% for Data Set C and 32.91% for the Then-Year Dollars Data Set.

Figure 13 is a graph of the constant dollar (Data Set C) averages presented in Table 15. Each cost category is plotted on the graph displaying its relative percentage of total cost over the period 1980 to 1986. The graph shows that the sample's total cost composition remained relatively stable for the seven year period.

Table 14

Descriptive Statistics
Cost/DL $ Ratio

Cost Per Direct Labor Dollar--Constant Dollars, Data Set C

	1980	1981	1982	1983	1984	1985	1986
AVERAGE	5.98	5.65	5.32	5.91	6.33	5.76	6.42
HIGH	9.85	9.78	12.87	18.57	9.42	11.03	11.49
LOW	2.71	2.17	2.52	2.67	2.68	2.94	3.07

Cost Per Direct Labor Dollar--Then Year Dollars

	1980	1981	1982	1983	1984	1985	1986
AVERAGE	5.98	5.53	5.01	5.39	5.88	5.24	5.59
HIGH	9.85	9.55	12.03	16.60	8.74	9.89	9.87
LOW	2.71	2.14	2.43	2.52	2.56	2.76	2.83

Table 15

Total Cost Composition

Constant Dollars, Data Set C

	1980	1981	1982	1983	1984	1985	1986	Avg
DL/TC	16.71%	17.69%	18.81%	16.92%	15.79%	17.35%	15.57%	16.98%
DM/TC	48.77%	41.27%	40.23%	41.37%	39.91%	38.50%	46.80%	42.41%
ODC/TC	5.28%	8.22%	8.10%	9.10%	13.17%	10.48%	8.14%	8.93%
OH/TC	29.24%	32.83%	32.86%	32.61%	31.15%	33.67%	29.50%	31.69%

Then-Year Dollars

	1980	1981	1982	1983	1984	1985	1986	Avg
DL/TC	16.71%	18.09%	19.95%	18.57%	17.02%	19.10%	17.90%	18.19%
DM/TC	48.77%	40.80%	38.28%	38.28%	36.74%	34.36%	40.78%	39.72%
ODC/TC	5.28%	8.46%	8.40%	9.37%	13.47%	10.71%	8.62%	9.19%
OH/TC	29.24%	32.65%	33.37%	33.78%	32.78%	35.83%	32.70%	32.91%

Note:

DL = Direct Labor; DM = Direct Material; ODC = Other Direct Charges;

OH = Overhead; TC = Total Cost

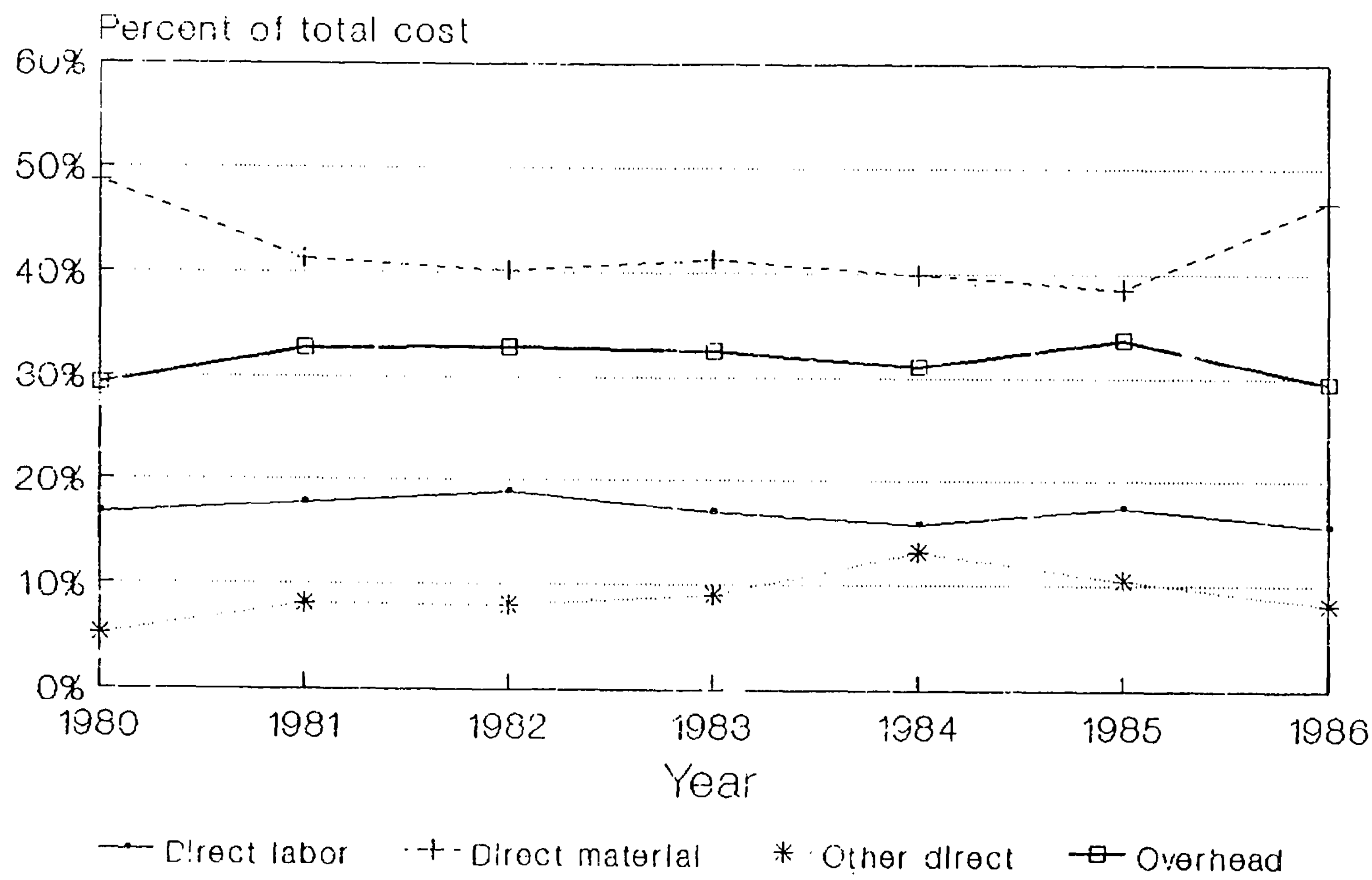

Figure 13. Graph of Total Cost Composition, Data Set C

Table 16 presents the composition of overhead costs for the Constant Dollar Data Set C and the Then-Year Dollars Data Set. 'Labor related' costs are the largest portion of overhead costs averaging 60.43 percent and 60.83 percent for the Constant Dollar and Then-Year Dollars Data Sets respectively. However, the 'labor related' cost category decreased relative to total overhead costs during the period, while the 'other' cost category exhibits a steady increase.

Figure 14 is a graph of the constant dollar averages presented in Table 16. Each overhead category is plotted on the graph showing its relative percentage of total overhead costs over the period 1980 to 1986. It is plain from the graph that 'labor related' costs decrease while 'other' costs increase during the period.

Finally, Figure 15 presents a set of pie charts that display the composition of total cost and overhead costs for 1980 and 1986. The figure provides a comparison of cost composition at the beginning and end of the study's time frame. The charts show that total cost composition is almost identical for both years. The pie charts also show that overhead cost composition changed little except that the 'labor related' cost category lost 12 percentage points to the 'other' overhead cost category.

Table 16

Overhead Cost Composition

Constant Dollars, Data Set C

	1980	1981	1982	1983	1984	1985	1986	Avg
L/OH	63.43%	65.61%	63.51%	63.30%	60.10%	55.96%	51.35%	60.46%
T/OH	2.16%	1.59%	1.48%	1.62%	1.19%	1.90%	2.11%	1.72%
DUO/OH	15.56%	14.12%	14.36%	14.26%	12.77%	15.93%	15.57%	14.65%
OTHR/OH	18.85%	18.69%	20.66%	20.82%	25.95%	26.22%	30.97%	23.16%

Then-Year Dollars

	1980	1981	1982	1983	1984	1985	1986	Avg
L/OH	63.43%	64.70%	62.73%	63.21%	60.87%	57.37%	53.50%	60.83%
T/OH	2.16%	1.62%	1.46%	1.56%	1.13%	1.79%	1.96%	1.67%
DUO/OH	15.56%	14.33%	14.72%	14.53%	12.78%	15.66%	14.97%	14.65%
OTHR/OH	18.85%	19.35%	21.09%	20.70%	25.21%	25.18%	29.58%	22.85%

Note:

L = Labor; T = Travel; DUO = Depreciation, Use, and Other;

OTHR = Other; OH = Overhead

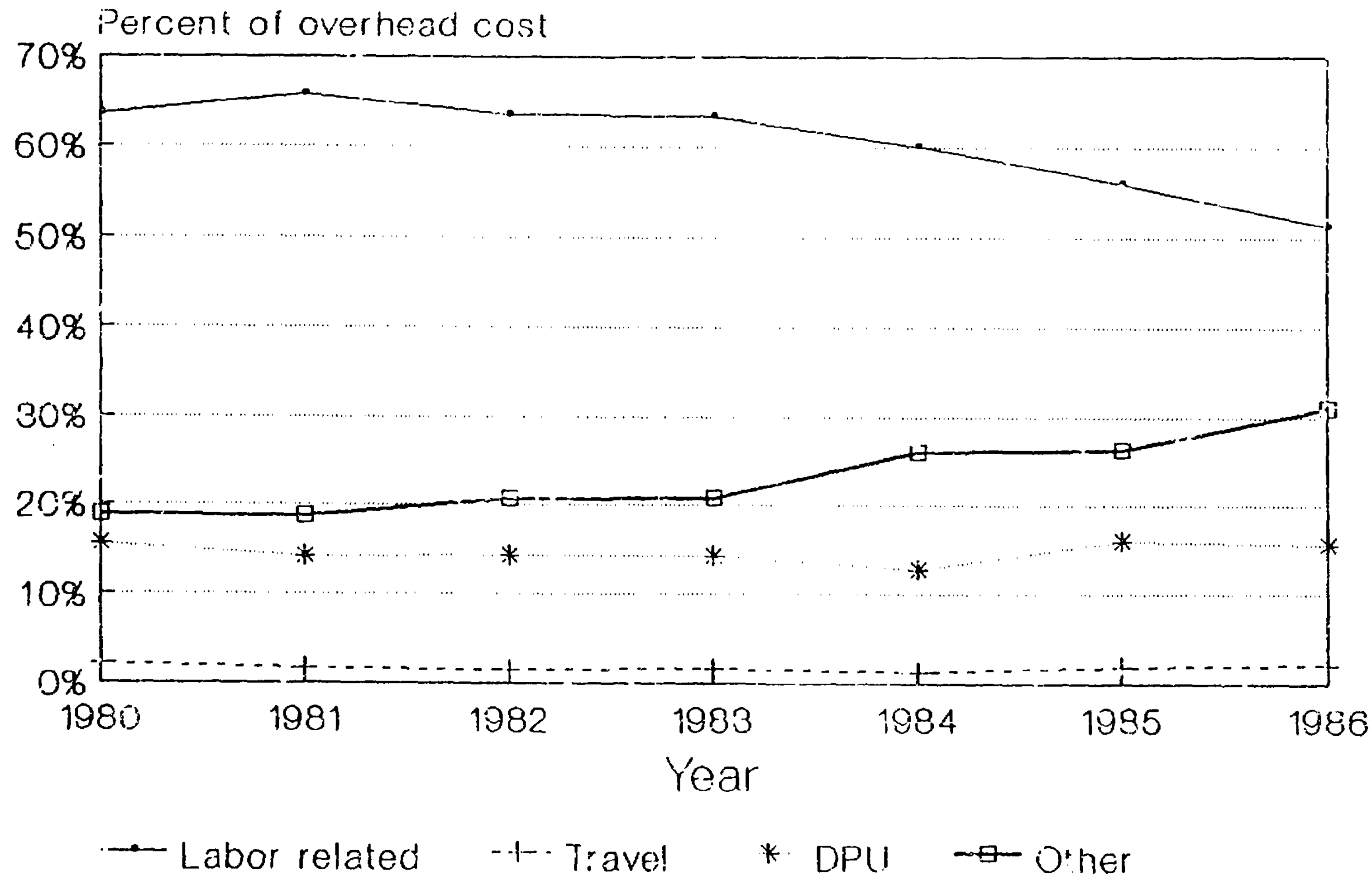

Figure 14. Graph of Overhead Cost Composition, Data Set C

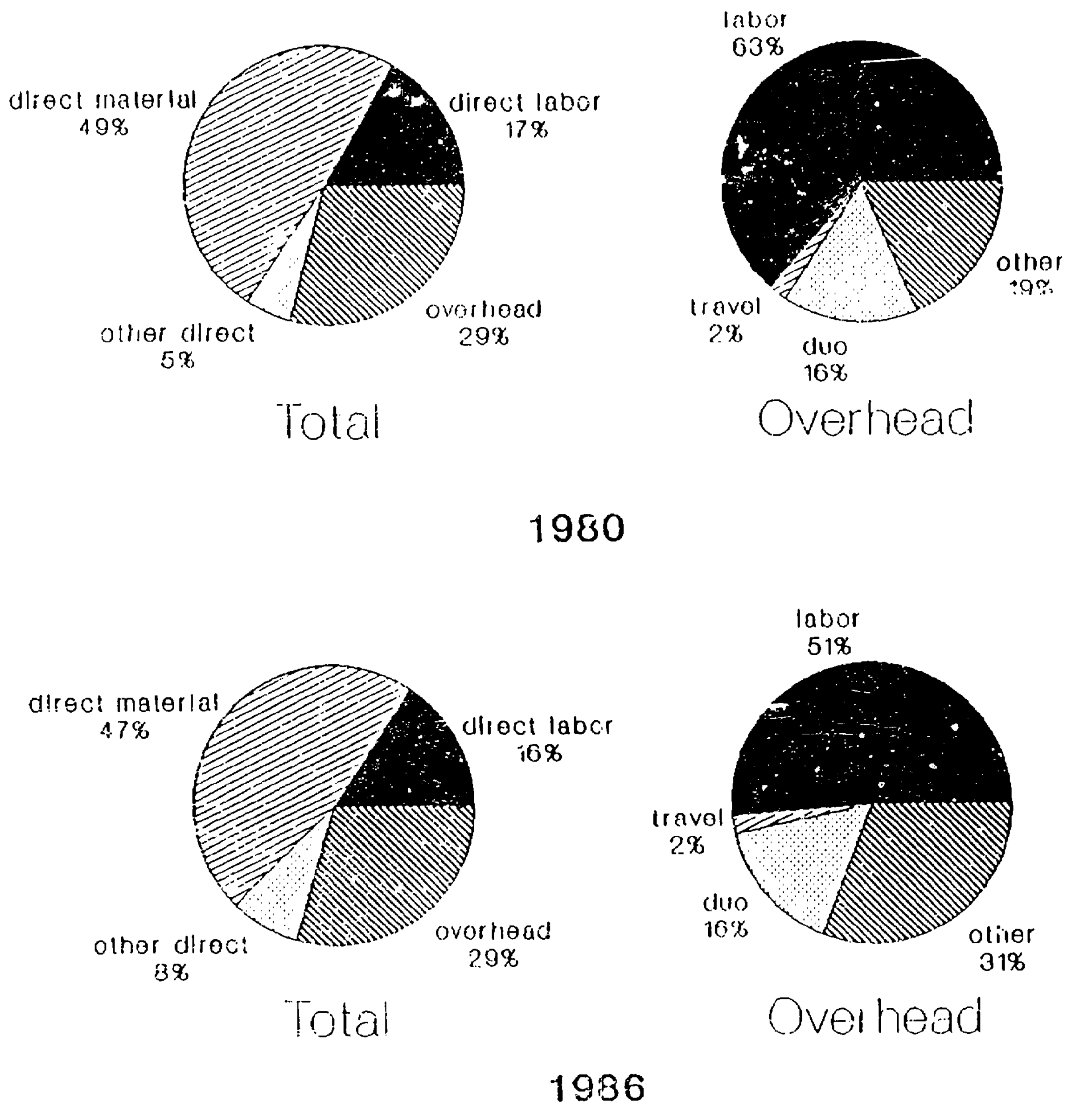

Figure 15. Cost Composition 1980 and 1986, Data Set C

Corollary Findings

This research focuses on testing the study's two hypotheses using the sample data as a whole. As discussed earlier, the test results do not support either of the hypotheses.

However, when the same hypothesis test (page 50) is applied to individual contractors using the dependent variables Cost/DL Hour and Cost/DL #, different results are obtained. Table 17 presents these results. Each contractor (A through P) is listed with its corresponding computed t values by applicable dependent variable and by the appropriate constant dollar or then-year dollar data set. Note that the critical t value is 2.015 for a one-tailed test at the 5% level of significance with five degrees of freedom (seven observations less two parameter estimates). The asterisks identify those contractors with t values that exceed the critical t value. The 'ALL' row at the bottom of the table allows for a comparison to the t values from the primary results presented in Table 9 on page 56.

Eight of the sixteen contractors have at least two computed t values that exceed the critical t values. The Then-Year Data Set produces the fewest significant t values (four) and Data Sets A and C produce the most (seven and eight respectively). Data Set B produces five significant t values.

These results indicate that as many as half of the contractors in the sample experienced significant increases in the ratios that are used by this study to measure relative

Table 17

Corollary Findings,
t Values for Individual Contractors,
Test of Hypothesis Number One
(Critical t Value = 2.015)

	Cost/DL Hour			Cost/DL $	
KTR	Data Set A	Data Set B	Data Set C	Data Set C	Then-Year Dollars
* A	3.611	2.934	3.385	3.402	2.913
B	0.775	0.436	1.128	1.127	0.272
C	-8.358	-7.193	-8.024	-8.005	-8.967
D	1.060	0.416	1.473	1.471	0.185
* E	2.491	1.790	2.456	2.448	1.547
F	-0.226	-0.792	-0.343	-0.344	-0.925
* G	1.910	1.444	2.106	2.101	1.241
* H	4.608	2.370	4.592	4.582	1.434
I	-0.558	-0.697	-0.483	-0.484	-0.746
J	-1.501	-2.051	-1.612	-1.616	-2.429
K	1.423	0.872	0.991	0.995	0.595
* L	7.714	7.186	6.229	6.235	7.155
* M	4.669	1.341	3.552	3.545	0.256
N	1.773	1.280	1.757	1.745	0.849
* O	2.602	2.470	2.469	2.469	2.198
* P	5.491	2.839	5.301	5.267	2.901
ALL	1.120	0.540	1.29	1.28	0.27

Note:

KTR = Contractor; * Identifies significant t values

cost growth. This is surprising given that the results of the original test for hypothesis number one indicate that the ratios did not experience significant increases during 1980 to 1986.

Appendix F contains a more complete set of hypothesis test results for the corollary findings. The parameter estimates are listed for the intercept term and the independent variable "year" by independent variable, constant dollar or then-year dollar data set and by contractor.

Summary

This chapter presents the results and findings of the study's data and statistical analyses. The primary results of the hypothesis tests do <u>not</u> support either of the study's two hypotheses. In addition, the K-S "goodness of fit" test result indicates that the sample's data comes from a population with a normal distribution. Also, the Durbin-Watson test produced results that indicate that no serious autocorrelation exists in the regression models. Descriptive statistics that further explain the sample's cost composition and cost trends are also presented. Finally, corollary findings about the cost growth behavior of individual contractors are included at the end of the chapter. The next chapter discusses the study's conclusions based on this chapter's findings. The last chapter also contains recommendations for additional research in the area of defense aerospace industry cost trends.

V. Conclusion

Introduction

The previous chapters describe the problem of weapon system cost growth and explain the composition and control of these costs. The objectives of this study are to determine if 'real' cost growth occurred in the industry during the period 1980 through 1986 and if the percentage of overhead cost to total cost increased during the same period. Based on these objectives, this study proposes the following hypotheses:

Hypothesis Number One, costs increased in the defense aerospace industry during the period 1980 through 1986.

Hypothesis Number Two, the percentage of overhead costs to total cost increased in the defense aerospace industry during the period 1980 through 1986.

The remainder of this chapter is divided into three sections. The first section summarizes 1) the primary results of the hypothesis tests; 2) the sample's descriptive statistics; and 3) the study's corollary findings. The second section discusses the significance of the study's results and defends the study's key assumption. The final section provides recommendations for future research.

Summary of Results

The literature review presented in the second chapter identifies assertions that 1) costs in the defense industry are increasing and 2) overhead costs are increasing and comprise a substantial portion of total weapon system cost. The empirical studies summarized in the literature review

present cost growth and cost composition trends of the 1960s and 1970s that basically support the cited assertions. The primary results of this study indicate the opposite to be true for total cost and overhead growth in the defense aerospace industry during the 1980 to 1986 time frame.

Hypothesis Number One. **Costs increased in the defense aerospace industry during the period 1980 through 1986.** The hypothesis test did not result in the rejection of the null hypothesis that the slope of the population regression line is zero. This indicates that costs did not increase in real terms in the defense aerospace industry during the period 1980 to 1986.

Hypothesis Number Two. **The percentage of overhead costs to total cost increased in the defense aerospace industry during the period 1980 through 1986.** The hypothesis test did not result in the rejection of the null hypothesis that the slope of the population regression line is zero. This indicates that overhead costs did not increase in relation to total costs in the defense aerospace industry during the period 1980 through 1986.

Descriptive Statistics. The descriptive statistics indicate, however, that the overhead cost component is a substantial portion of total cost in the industry. In the sample tested, overhead is the second largest component of total cost averaging 31.7% for the seven year period. Direct material is the largest with a 42.4% average share of total cost. Direct labor is third at 17% and other direct charges

has the smallest share averaging 8.9%. All of the above percentages were computed using Constant Dollar Data Set C.

The overhead cost component is mainly composed of "labor related" expenses which average 60.8% of its total. "Other" costs average 22% of total overhead; "depreciation, use, and occupancy" costs average 15.6%; and "travel" expenses average only 1.6%. Again, all of the percentages were computed using Constant Dollar Data Set C.

Corollary Findings. The corollary findings indicate that as many as half of the sixteen contractors in the sample experienced significant cost growth during the seven year period. When the hypothesis test is applied against individual contractors, the null hypothesis is rejected in eight of the sixteen tests under Constant Dollar Data Set C for the dependent variables "Cost/DL Hour" and "Cost/DL $". Constant Dollar Data Sets A and B, with the dependent variable "Cost/DL $, produce seven and five null hypothesis rejections respectively and the Then-Year Dollars Data Set produces only four null hypothesis rejections.

Discussion of the Study's Results

The study's primary results indicate that there is no "real" cost growth in the defense aerospace industry, when taken as a whole, during the period 1980 to 1986. In addition, the percentage of overhead costs to total cost did not increase in the industry. The results are based on cost data generated during a period of increasing activity in the industry. These cost trends occur during a time when defense

aerospace spending increased (ITA-85:37-1 and AW&ST:18-19) and the industry's excess capacity decreased (ITA-85:37-1). Cost growth and cost composition may exhibit different trends when industry activity is stagnant or decreasing.

The corollary findings prove interesting because they indicate that as many as eight of the contractors in the sample experienced a significant increase in the ratios Cost/DL Hour and Cost/DL $. Since this study assumes that these ratios are a viable measure of industry cost growth, the results indicate that half of the contractors in the sample experienced significant cost growth.

It is surprising that such a large number of contractors in the sample produce results that contradict the primary findings. A reason for such conflicting results may be the wide dispersion of the data points (Cost/DL Hour and Cost/DL $ ratios). Figures 5 through 9 in the fourth chapter display the extent of this dispersion. The wide dispersion of data points may be caused by the various segments of the aerospace industry. For example, the aircraft industry segment may be subject to a different set of factors that affect cost than the guided missiles and space vehicles segment.

However, since this study's hypotheses are based on defense aerospace industry trends rather than individual contractors or industry segments, it is more appro[illegible]ate to base any conclusions on the primary results. Therefore, it is inferred from the primary results that there was no significant real cost growth or overhead cost growth relative

to total cost in the defense aerospace industry during the seven period 1980 to 1986.

The results also show that the overhead cost component has the second largest share of total cost. This finding is the same as the findings of the three empirical studies reviewed in the second chapter. These empirical studies show raw material costs comprising the largest share of total cost followed by overhead. Over time (1981 to 1986), it appears that cost composition has remained remarkably stable with the major cost categories comprising about the same share of total cost.

This stability was not expected at the start of the study. The DOD initiative to "modernize" the defense industrial base to make it more automated and efficient (6:37) should have a measurable impact on total cost composition. Much of the literature on factory modernization states that as factories automate, overhead costs grow and direct costs (specifically direct labor) shrink in relation to total cost (22:143 and 31:47). The results of this study indicate that any modernization of defense aerospace factories that occurred before 1986 was not significant enough to generate changes in cost composition.

The composition of overhead costs have not remained as stable as the composition of total costs. Basically, "labor related" costs have steadily decreased while "other" costs have increased. This statistic may be misleading, however, since labor costs, in the form of services, make up a

substantial portion of the 'other' cost category. Perhaps a more meaningful breakout of overhead categories should include a category for service costs. This category would contain the costs of all interdepartmental and outside services. Such a categorization would be beneficial because these costs seem to be growing faster than the other overhead categories and for this reason require more visibility.

In the defense aerospace industry of the 1980s, overhead is an important component of total cost not only because of its relative size, but also because it is not as controllable as direct costs. Although the results of this study indicate that the percentage of overhead costs to total cost did not increase during the period 1980 to 1986, these costs still are a significant component of total industry costs.

Future defense spending is expected to decrease (11:170). A decrease in defense business will likely lead to increases in the aerospace industry's excess capacity which can result in higher overhead costs (27:24 and 11:170). Therefore, the DOD's initiative of overhead cost control should continue.

Study's Key Assumption

The findings of this study depend on the propriety of using financial ratios as the dependent variables in the hypothesis tests. In particular, are direct labor hours and direct labor dollars reliable surrogates for industry output?

The study required an adequate measure of output to arrive at a relative measure of cost growth in the form of a cost per unit figure. Since actual industry output measured

by "units produced" was not available, a surrogate measure of output was adopted. This surrogate was direct labor: direct labor hours and direct labor dollars.

It is assumed that direct labor fluctuates with sales and is actually a function of sales. Further, production activity and production costs are generated by sales. This is especially true in the aerospace industry, where, because of the cost and uniqueness of the products, production is based on specific sales orders.

There is some evidence in the aerospace industry to support the contention that direct labor is a function of sales. During the 1982 to 1983 time frame, the industry experienced a noticeable decline in sales. The industry's direct labor employment declined over the same two years. In addition, the direct labor hours used in this study are at their lowest level in 1983.

Also, other studies have used labor as a surrogate measure for output. For example, the Kaitz and Associates study that was reviewed in the second chapter used employment levels "as an approximate surrogate for capacity utilization rates" in an industry (27:26).

If the above assumption is true, then using the Cost per Direct Labor Hour and Cost per Direct Labor Dollar ratios as a relative measure of cost growth should be a legitimate option. It is a legitimate option because as sales fluctuate production and direct labor will fluctuate. Therefore, the amount of direct labor hours or direct labor dollars should

provide an indication of the level of output. As the ratios increase, more costs are being incurred in the production effort that are due to factors other than sales growth.

However, changes in the level of direct labor caused by factors other than sales fluctuations is a possibility and may influence this study's results. For example, high levels of capital investment that increases a plant's automation may increase labor productivity. This situation may reduce the number of direct labor hours used to produce the same amount of output and also increase overhead costs. The result is an increase in the cost per direct labor hour while unit costs decrease or remain the same. However, the aerospace has a history of low levels of capital investment and high levels of labor intensive work (11:224-227). Therefore, the impact of factory automation as described in the preceding example should not have had a significant impact on the study's results.

Recommendations for Future Research

Many areas exist for further research of weapon system cost growth and composition. This section recommends a few areas for future study.

Industry operating variables such as excess capacity levels, plant size, levels of capital investment, and employment levels should be investigated to determine their relationship to cost growth and composition. This study would be beneficial because identifying operating variables that

significantly influence cost would help focus efforts to control costs.

A comparison of the costs of plants that are considered to be "highly" automated to the costs of plants that are more labor intensive, but which manufacture similar items would be beneficial. Information on how cost composition differs between automated and labor intensive factories may identify significant cost generators for each type of factory. Some interesting comparisons could probably be made on how the composition of costs change between automated and less automated plants.

Repeat this study or a similar study in the 1990s to determine if the predicted decrease in defense spending or if industrial modernization initiatives have had any impact on industry costs. Although a time span of about seven to ten years is necessary before the study can be completed, it should provide interesting results that can be compared to this study's findings.

Confine this study or a similar study to certain aerospace industry segments. Some of the segments are the aircraft industry (SIC code 3721), the aircraft engines and engine parts industry (SIC code 3724), and the guided missiles and space vehicles industry (SIC code 3726). Cost behavior may be very different between the industry segments than reflected for the industry as a whole.

Select a sample of 1980 to 1986 aerospace weapon system contracts and see if the results of this study can be

replicated. The results of this study make inferences about the defense aerospace industry. It would be interesting to note whether the same conclusions can be drawn about aerospace contracts during the same seven year period.

Finally, an investigation of nonlinear models to forecast aerospace industry costs would be beneficial. Such a model or models may help managers better plan future acquisition budgets.

Appendix A: HQ AFCMD Standardized Breakout of Overhead Cost Categories (14)

Indirect Labor: All wages/salaries paid to personnel classified as indirect, including overtime or premium pay for indirect personnel and any overtime or premium pay for direct personnel that may be charged indirect. Also wages/salaries paid to personnel classified as direct but charging indirect (divisionary or crossover labor).

Payroll Taxes: Federal and state statutory employment tax and insurance payments. If such costs are classified as a direct charge at your location for direct labor, report the amount as a separately identified subset of this category.

Fringe Benefits: Employer-provided group insurance costs (health, life, etc.); sick, vacation and holiday leave plan costs; savings and retirement/pension plan costs. If such costs are classified as a direct charge for direct labor, report the amount as a separately identified subset of this category.

Travel: All non-labor travel expenses other than direct charge travel and travel via contractor-owned, leased or chartered aircraft.

Travel via Contractor-Owned, Leased, or Chartered Aircraft: All acquisition or depreciation, maintenance, supply, refurbishment and operating costs; all non-labor pilot/crew costs including training and certification; all non-labor airport/runway construction, depreciation, and maintenance costs.

Depreciation: All depreciable assets (other than aircraft/airport assets) including buildings, capitalized renovations, industrial plant equipment, furnishings, capital leases and other capital assets.

Use and Occupancy: All utilities; non-labor remodeling, relocation and moving expenses; non-labor security costs; maintenance and housekeeping supplies and materials; non-capital leases/rentals.

Taxes and Insurance: All property taxes, federal and state income/gross receipts taxes, franchise taxes, product liability insurance, fire/hazard insurance, other non-employment taxes and insurance costs.

Other: All other non-labor costs not otherwise included above. Any significant subset (i.e. 30% or more of the total "other" category) should be separately identified.

Appendix B: Classification of Overhead Cost Categories

A. LABOR RELATED

Indirect Salaries
Outside Services
IR&D/Bid and Proposal
Direct Non-Worked
Professional Services
Plant Engineering
Controllable Expenses
Administrative Services
Employment
Recruiting
Production
Administration
Future Business
Salaries and Wages
Payroll Allowances
Other Indirect Labor
Marketing Expense
Sales Promotion Expense
Service Allocation
General Allocation
Legal
Selling Expenses
Services Purchased
Accrued Salary Allowances
Management Services
Diverted Labor
Labor Premium
Indirect and Direct Employees
Redistributed Services
Program/Project Management
Division Services
Central Services
General and Administrative
Payroll Taxes
Fringe Benefits
Severance Pay
Employee Benefits
Labor Benefits
Retirement Group Medical
Incentive Compensation
Direct Fringe
Insurance Retirement
Career Service Plan
Incentive Compensation
Indirect Hourly
Indirect Salary
Building Support Services
Service Pool
Common Support
Personnel Services
Payroll Expenses
Plant Services
Indirect Payroll Expense
DSC O/H Staff
OSG O/H Staff
Staff Allocation
Management Fees Allocation

B. TRAVEL

Travel
Communication/Travel

C. DEPRECIATION, USE, and OCCUPANCY

Facility Distribution	Site Restoration
Overhead Redistributed	Material Allocation
Depreciation and Amortization	Indirect Supplies
Facility Related	Perishable Tools/Equipment
Corporate Exp.--Environmental	Indirect Material
Contemp Environment	Fixed Expenses
Facilities Equipment	Sundry
Facilities: Bldg/Land	Material and Supplies
Facilities: Furn/Equip	Fixed and Semi-Fixed
Operating Expense	Repair and Maintenance
Depreciation, Insurance	Equipment Rental
Equipment Depreciation	Energy Expense
Operational Supplies	Heat, Light, and Power
Office Supplies	Occupancy
Rental and Leases	Usage Material
Relocation	Space Occupancy
Rent	Equipment Expense
Utilities	Material Burden

D. OTHER

Insurance	Other Assigned Expenses
Franchise Tax	DGO Expense
Taxes	Micro Electronics Center
Product Liability Insurance	Provisional Billing Hold
Conference and Technical Meeting	OSG Allocation
Other	MICP--Incentive
Value Added	Computing
Communication	International
Computer	Procurement
Miscellaneous Transfers	Logistic Support Rate
Other Controllable	Preservice and Package
Corporate Expense	Indirect Data Processing
Other Noncontrollable	ADPE
Recruiting	Services Credited
Telephone & Telegraph	Packing/Crating/Freight
Other Departmental	Transfers, Allocations
Allocations--Corporate	Indirect Mixed Accounts
Allocations	Information Systems
CDSC (computer)	Telecommunications
Potential Unallowable	Off Book Adjustment
Credits	Transfers to Other Pools
Other Operating Expenses	Direct Diversions
Assessed Expenses	Period Costs
Within Group	General
Within Group--Transfer Out	Group Expenses
Production Related	Other Allocated Expenses
CITE	Technical Mktg Authority
Voluntary Deductions--Credits	Charges from ISC
Rep Commission	Other Assigned Expenses

Appendix C: Rationale for Selected Price Indexes

The following is an explanation of the rationale for selecting the price indexes used to compute the constant dollar Data Sets A, B, and C.

Data Set A is discounted by the Producer Price Index (PPI) for Industrial Commodities--Transportation Equipment (36:27). This price index is computed by the Bureau of Labor Statistics (BLS) based on price level changes in the transportation equipment industry. The Department of Commerce classifies the aerospace as belonging to the transportation industry. Therefore, defense aerospace industry costs should be subject to about the same price level changes as those reflected in this index.

Data Set B is discounted by the Industry Shipments Price Index for the aerospace industry (37:39-2,39-3). This price index is computed by the International Trade Administration of the Commerce Department based on price level changes in the aerospace industry. Defense aerospace industry price changes should correspond to those reflected in this index.

Data Set C is discounted by a number of price indexes based on the cost category involved in the conversion. The

rationale for such a procedure is that each cost category is influenced by different inflationary pressures which result in different price level changes. The following is a list of each cost category and its applicable price index with accompanying explanation.

Direct Labor Costs are discounted by an average hourly wage rate for aerospace production workers index. This index is computed based on the average hourly wage rates for aerospace production workers published in U S Industrial Outlook 1983 (37). As such, it should accurately reflect the price level changes of aerospace industry production workers.

Direct Material Costs are discounted by the Producer Price Index (PPI) for Intermediate Materials (36:27). The argument for using this index is that very little of the material used by the contractors in this study is raw material. Most of the material is preprocessed. Therefore, this index should adequately reflect the price changes for direct material.

Other Direct Charges are discounted by the PPI for Industrial Commodities--Transportation Equipment. (36:2[illegible]). Since Other Direct Charges include both labor material expenses and labor charges, a more generic price index is used to discount the costs.

Overhead--Labor Related costs are discounted by the Employment Cost Index for White Collar Workers (36:60). This price index is computed based on price level involving the compensation of professional, specialty, and technical occupations: executive, administrative, and managerial occupations; sales occupations and administrative support occupations including clerical (36:71). These same occupations make up the Labor Related category of overhead costs

Overhead--Travel costs are discounted by the Consumer Price Index (CPI), for Public Transportation (36:25). Most travel expenses include public transportation costs. Therefore, this price index should adequately reflect the price level changes for the travel category.

Overhead--Depreciation, Use, and Occupancy costs are discounted using an average of three price indexes. These indexes are the PPI for Industrial Commodities--Machinery and Equipment; the PPI for Industrial Commodities--Capital Equipment; and the CPI for Fuel and Utilities--Piped Gas and Electricity (36:25, 28). These indexes were chosen based on the composition of costs in the Depreciation, Use, and Occupancy category.

Overhead--Other costs are discounted using the PPI for Industrial Commodities--Transportation Equipment. Since the Other category contains a variety of costs including labor related, materials, and services, a more generic price index is used to discount the costs.

Appendix D: Sample's Annual Costs by Cost Category in Then-Year and Constant Dollars
(In Millions of Dollars)

Then-Year Dollars

YEAR	1980	1981	1982	1983	1984	1985	1986
DL	4,123	4,577	5,036	4,902	5,437	6,527	7,164
DM	12,032	10,322	9,665	10,107	11,739	11,745	16,319
ODC	1,303	2,140	2,120	2,475	4,304	3,661	3,448
OH							
LR	4,576	5,343	5,285	5,637	6,375	7,026	7,000
TRAVEL	156	134	123	139	119	220	257
D/U/O	1,122	1,184	1,240	1,295	1,339	1,918	1,958
OTHER	1,360	1,598	1,776	1,846	2,641	3,083	3,870
OH TOT	7,214	8,259	8,424	8,917	10,473	12,246	13,085
TOT COST	24,672	25,298	25,246	26,402	31,953	34,178	40,017

Constant Dollars, Data Set A:

YEAR	1980	1981	1982	1983	1984	1985	1986
DL	4,123	4,026	4,176	3,953	4,285	5,013	5,375
DM	12,032	9,078	8,014	8,151	9,251	9,020	12,242
ODC	1,303	1,882	1,758	1,996	3,302	2,812	2,587
OH							
LR	4,576	4,699	4,382	4,546	5,024	5,396	5,251
TRAVEL	156	118	102	112	93	169	193
D/U/O	1,122	1,041	1,028	1,045	1,055	1,473	1,469
OTHER	1,360	1,405	1,473	1,489	2,081	2,368	2,903
OH TOT	7,214	7,263	6,985	7,191	8,253	9,405	9,816
TOT COST	24,672	22,250	20,933	21,292	25,180	26,251	30,020

Note:

DL = Direct Labor
DM = Direct Material
ODC = Other Direct Charges
OH = Overhead
LR = Labor Related
D/U/O = Depreciation, Use, and Occupancy

Constant Dollars, Data Set B:

YEAR	1980	1981	1982	1983	1984	1985	1986
DL	4,123	4,065	4,045	3,754	3,938	4,751	5,136
DM	12,032	9,167	7,763	7,739	8,632	8,548	11,698
ODC	1,303	1,901	1,703	1,895	3,165	2,664	2,472
OH							
LR	4,576	4,745	4,245	4,316	4,688	5,113	5,108
TRAVEL	156	119	99	106	87	160	184
D/U/O	1,122	1,051	996	992	984	1,396	1,404
OTHER	1,360	1,419	1,427	1,414	1,942	2,244	2,774
OH TOT	7,214	7,334	6,767	6,828	7,701	8,913	9,380
TOT COST	24,672	22,476	20,278	20,216	23,495	24,875	28,686

Constant Dollars, Data Set C:

YEAR	1980	1981	1982	1983	1984	1985	1986
DL	4,123	4,051	4,081	3,711	4,067	4,656	4,948
DM	12,032	9,452	8,731	9,073	10,279	10,329	14,876
ODC	1,303	1,882	1,758	1,996	3,392	2,812	2,587
OH							
LR	4,576	4,934	4,529	4,528	4,819	5,054	4,814
TRAVEL	156	119	105	116	95	171	198
D/U/O	1,122	1,062	1,024	1,020	1,024	1,439	1,460
OTHER	1,360	1,405	1,473	1,489	2,081	2,368	2,903
OH TOT	7,214	7,520	7,131	7,153	8,018	9,032	9,376
TOT COST	24,672	22,905	21,701	21,933	25,756	26,829	31,786

Note:

DL = Direct Labor
DM = Direct Materials
ODC = Other Direct Charges
OH = Overhead
LR = Labor Related
D/U/O = Depreciation, Use, and Occupancy

Appendix E. Financial Ratios Used In the Statistical Tests

Cost Per Direct Labor Hour--Constant Dollars, Data Set A

KTR	1980	1981	1982	1983	1984	1985	1986
A	41.29	45.24	53.76	54.77	46.91	65.71	64.52
B	66.40	54.30	47.10	55.63	75.70	56.23	69.39
C	83.55	78.54	65.71	66.[illegible]9	57.81	57.42	52.06
D	97.47	94.02	82.64	84.34	87.27	105.44	106.16
E	26.80	21.10	24.65	26.56	26.72	29.46	30.46
F	46.10	41.34	43.79	52.92	51.51	46.91	38.[illegible]
G	62.66	72.85	57.60	55.76	84.27	81.83	8[illegible].23
H	37.35	39.71	39.78	39.62	44.08	42.13	44.59
I	86.29	83.85	121.88	175.12	91.14	[illegible]7.01	73.54
J	71.04	61.16	53.39	57.60	60.87	56.96	57.91
K	50.65	64.52	69.53	70.59	62.94	69.26	65.53
L	32.97	33.38	37.78	48.31	62.83	61.14	80.14
M	38.40	38.76	39.77	40.51	41.72	40.31	43.02
N	37.10	46.36	48.18	47.88	53.41	49.67	46.53
O	33.82	39.03	41.71	58.56	53.51	56.56	49.17
P	41.20	43.85	44.28	44.91	45.42	51.95	52.21

Cost Per Direct Labor Hour--Constant Dollars, Data Set B

KTR	1980	1981	1982	1983	1984	1985	1986
A	41.29	45.68	52.08	52.01	43.77	62.27	61.65
B	66.40	54.83	45.63	52.82	70.63	53.28	66.78
C	83.55	79.31	63.65	62.84	53.95	54.41	49.74
D	97.47	94.94	80.05	80.07	81.43	99.92	101.44
E	26.80	21.30	23.88	25.22	24.93	27.92	29.11
F	46.10	41.75	42.42	50.24	43.06	43.50	36.50
G	62.66	73.56	55.79	52.94	78.63	77.54	78.58
H	37.35	40.10	38.53	37.61	41.13	39.92	42.61
I	86.29	8[illegible].67	118.06	166.27	85.04	54.02	70.27
J	71.04	61.76	51.72	54.69	56.80	53.97	55.34
K	50.65	65.15	67.35	67.02	58.73	65.63	62.61
L	32.97	33.71	36.60	45.87	58.62	57.93	76.58
M	38.40	39.14	38.52	38.46	38.93	38.20	41.11
N	37.10	46.81	46.68	45.46	49.84	47.06	44.46
O	33.82	39.47	40.41	55.61	49.93	53.59	46.99
P	41.20	44.28	42.89	42.64	42.38	49.23	49.89

Note:

KTR = Contractor

Cost Per Direct Labor Hour--Constant Dollars, Data Set C

KTR	1980	1981	1982	1983	1984	1985	1986
A	41.29	46.43	55.40	56.43	47.09	65.80	65.62
B	66.40	55.88	49.07	58.03	78.69	58.93	75.52
C	83.55	81.01	69.04	69.27	59.87	59.56	56.62
D	97.47	96.88	86.15	87.31	89.51	109.19	113.77
E	26.80	21.51	25.00	26.44	26.49	29.07	30.39
F	46.10	42.47	45.19	54.36	51.77	45.98	37.98
G	62.66	75.44	59.17	55.97	87.94	85.36	88.47
H	37.35	40.87	41.24	40.42	45.25	43.26	46.83
I	86.29	86.52	127.41	183.91	93.27	56.54	79.54
J	71.04	62.93	55.07	58.24	61.31	57.84	59.33
K	50.65	66.65	71.82	71.63	62.84	68.41	65.15
L	32.97	34.30	38.56	48.41	62.75	61.09	89.16
M	38.40	39.66	40.56	40.65	41.97	40.31	43.99
N	37.10	47.50	49.69	49.37	54.53	49.99	48.05
O	33.82	40.09	42.34	59.84	54.32	56.23	49.62
P	41.20	45.10	45.80	45.88	46.10	52.94	54.31

Cost Per Direct Labor Dollar--Constant Dollars, Data Set C

KTR	1980	1981	1982	1983	1984	1985	1986
A	4.17	4.69	5.59	5.70	4.76	6.65	6.63
B	6.71	5.64	4.96	5.86	7.95	5.95	7.63
C	8.44	8.18	6.97	7.00	6.05	6.02	5.72
D	9.85	9.78	8.70	8.82	9.04	11.03	11.49
E	2.71	2.17	2.52	2.67	2.68	2.94	3.07
F	4.66	4.29	4.56	5.49	5.23	4.64	3.84
G	6.33	7.62	5.98	5.65	8.88	8.62	8.93
H	3.77	4.13	4.16	4.08	4.57	4.37	4.73
I	8.72	8.74	12.87	18.57	9.42	5.71	8.03
J	7.18	6.36	5.56	5.88	6.19	5.84	5.99
K	5.12	6.73	7.25	7.23	6.35	6.91	6.58
L	3.33	3.46	3.89	4.89	6.34	6.17	9.00
M	3.88	4.00	4.10	4.11	4.24	4.07	4.44
N	3.75	4.80	5.02	4.99	5.51	5.05	4.85
O	3.42	4.05	4.28	6.04	5.49	5.68	5.01
P	4.16	4.55	4.62	4.63	4.65	5.35	5.48

Note:

KTR = Contractor

Cost Per Direct Labor Dollars--Then-Year Dollars

KTR	1980	1981	1982	1983	1984	1985	1986
A	8.00	4.60	5.31	5.19	4.50	6.16	6.00
B	6.71	5.52	4.65	5.27	7.26	5.27	6.50
C	8.44	7.98	6.49	6.27	5.54	5.39	4.34
D	9.85	9.55	8.16	8.00	8.36	9.89	9.87
E	2.71	2.14	2.43	2.52	2.56	2.76	2.83
F	4.66	4.20	4.32	5.02	4.94	4.31	3.55
G	6.33	7.40	5.68	5.29	8.08	7.68	7.64
H	3.77	4.04	3.93	3.76	4.22	3.95	4.14
I	8.72	8.52	12.03	16.60	8.74	5.35	6.84
J	7.18	6.21	5.27	5.46	5.83	5.34	5.38
K	5.12	6.56	6.86	6.69	6.03	6.50	6.09
L	3.33	3.39	3.73	4.58	6.02	5.74	7.45
M	3.88	3.94	3.92	3.84	4.00	3.78	4.00
N	3.75	4.71	4.76	4.54	5.12	4.66	4.32
O	3.42	3.97	4.12	5.55	5.13	5.31	4.57
P	4.16	4.46	4.37	4.26	4.35	4.87	4.85

Percentage of Overhead Costs to Total Cost--Constant Dollars,
Data Set C

KTR	1980	1981	1982	1983	1984	1985	1986
A	38.69%	37.80%	38.73%	38.14%	39.68%	49.66%	46.08%
B	18.66%	22.29%	21.30%	20.40%	18.51%	21.14%	22.65%
C	18.31%	17.66%	20.05%	20.26%	23.35%	27.14%	19.77%
D	36.71%	40.37%	38.32%	40.52%	42.16%	40.81%	31.77%
E	36.59%	33.07%	39.01%	40.48%	40.54%	41.23%	40.65%
F	40.43%	35.61%	39.69%	36.62%	40.85%	40.45%	38.00%
G	45.77%	63.79%	43.22%	44.36%	28.86%	32.53%	28.98%
H	31.27%	26.57%	27.62%	29.09%	23.82%	24.99%	27.78%
I	29.72%	31.52%	35.70%	34.08%	34.12%	55.03%	29.05%
J	39.60%	40.97%	41.92%	49.14%	39.72%	40.93%	37.12%
K	52.89%	61.11%	60.88%	61.00%	59.26%	60.40%	55.44%
L	54.96%	61.22%	50.68%	42.18%	35.50%	31.49%	21.45%
M	51.55%	50.04%	50.41%	49.35%	41.58%	43.24%	43.82%
N	40.91%	32.38%	32.61%	28.64%	27.23%	29.54%	28.63%
O	45.26%	44.38%	44.46%	38.58%	37.36%	38.95%	37.50%
P	38.22%	40.91%	40.46%	41.82%	41.73%	41.32%	38.68%

Note:

KTR = Contractor

Percentage of Overhead Costs to Total Cost--Then-Year Dollars

KTR	1980	1981	1982	1983	1984	1985	1986
A	38.69%	37.59%	39.26%	39.55%	41.04%	51.87%	49.09%
B	18.66%	22.21%	21.76%	21.40%	19.72%	23.01%	25.56%
C	18.31%	17.60%	20.62%	21.31%	24.90%	29.55%	22.53%
D	36.71%	40.43%	39.26%	42.15%	44.37%	43.72%	35.88%
E	36.59%	32.88%	38.98%	40.53%	41.25%	42.53%	42.72%
F	40.43%	35.32%	40.13%	37.86%	42.42%	42.15%	39.74%
G	45.77%	63.21%	43.17%	44.78%	31.25%	35.75%	32.83%
H	31.27%	26.27%	27.89%	29.84%	25.35%	26.98%	31.01%
I	29.72%	31.33%	36.50%	36.02%	36.07%	56.96%	32.96%
J	39.60%	40.77%	42.34%	49.86%	41.22%	43.12%	39.77%
K	52.89%	14.73%	14.85%	16.22%	19.24%	22.74%	58.78%
L	54.96%	60.66%	50.64%	42.50%	36.34%	32.41%	24.69%
M	51.55%	49.86%	50.54%	49.72%	42.95%	44.78%	45.87%
N	40.91%	31.98%	32.96%	29.83%	28.81%	31.11%	31.23%
O	45.26%	43.91%	44.31%	37.62%	38.98%	40.46%	39.05%
P	38.22%	40.87%	41.12%	42.92%	43.42%	43.70%	42.21%

Note:

KTR = Contractor

Appendix F. Statistical Results By Contractor For Hypothesis Number One

Cost Per Direct Labor Hour, Data Set A:

CONTRACTOR YEAR	PARAMETER ESTIMATE	STANDARD ERROR	t VALUE
KTR=A			
INTERCEP	-7296.68	2035.67205	-3.584
YEAR	3.70642857	1.02656128	3.611
KTR=B			
INTERCEP	-2979.61	3922.25336	-0.760
YEAR	1.53321429	1.97793816	0.775
KTR=C			
INTERCEP	10307.38393	1225.55686	8.412
YEAR	-5.16464	0.61793053	-8.358
KTR=D			
INTERCEP	-3697.87	3578.83317	-1.033
YEAR	1.91214286	1.80475610	1.060
KTR E			
INTERCEP	-2081.82	846.42329035	-2.460
YEAR	1.06321429	0.42683957	2.491
KTR=F			
INTERCEP	530.10000000	2141.81795	0.248
YEAR	-0.244286	1.08008919	-0.226
KTR=G			
INTERCEP	-7247.66	3832.32681	-1.891
YEAR	3.69071429	1.93258944	1.910
KTR=H			
INTERCEP	-2144.51	474.29489631	-4.521
YEAR	1.10214286	0.23918036	4.608
KTR=I			
INTERCEP	8786.06893	15580.00056	0.564
YEAR	-4.38107	7.85677894	-0.558

CONTRACTOR VARIABLE	PARAMETER ESTIMATE	STANDARD ERROR	t VALUE
KTR=J			
INTERCEP	2014.65893	1902.39940	1.532
YEAR	-1.43964	0.95935372	-1.501
KTR=K			
INTERCEP	-3301.43	2366.29542	-1.395
YEAR	1.69750000	1.19329007	1.423
KTR=L			
INTERCEP	-15677.1	2038.99038	-7.689
YEAR	7.93142857	1.02823467	7.714
KTR=M			
INTERCEP	-1298.88	286.81469059	-4.529
YEAR	0.67535714	0.14463666	4.669
KTR=N			
INTERCEP	-2795.75	1602.94281	-1.744
YEAR	1.43357143	0.80834190	1.773
KTR=O			
INTERCEP	-6525.45	2526.42833	-2.583
YEAR	3.31464286	1.27404289	2.602
KTR=P			
INTERCEP	-3521.02	649.66834427	-5.420
YEAR	1.79892857	0.32761877	5.491

Cost Per Direct Labor Hour, Data Set B

CONTRACTOR VARIABLE	PARAMETER ESTIMATE	STANDARD ERROR	t VALUE
KTR=A			
INTERCEP	-6035.85	2074.43406	-2.910
YEAR	3.06964286	1.04610842	2.934
KTR=B			
INTERCEP	-1573.1	3738.72193	-0.421
YEAR	0.82285714	1.88538579	0.436
KTR=C			
INTERCEP	11461.21393	1584.59836	7.233
YEAR	-5.7475	0.79909105	-7.193

CONTRACTOR VARIABLE	PARAMETER ESTIMATE	STANDARD ERROR	t VALUE
KTR=D			
INTERCEP	-1555.84	3956.03126	-0.393
YEAR	0.83035714	1.99497189	0.416
KTR=E			
INTERCEP	-1477.24	839.68265209	-1.759
YEAR	0.75785714	0.42344036	1.790
KTR=F			
INTERCEP	1436.43071	1758.05855	0.817
YEAR	-0.702143	0.88656463	-0.792
KTR=G			
INTERCEP	-5495.2	3854.26219	-1.426
YEAR	2.80571429	1.94365115	1.444
KTR=H			
INTERCEP	-1236.59	538.48051683	-2.296
YEAR	0.64357143	0.27154828	2.370
KTR=I			
INTERCEP	10178.50071	14475.19086	0.703
YEAR	-5.085	7.29963868	-0.697
KTR=J			
INTERCEP	4137.21714	1988.46595	2.081
YEAR	-2.05714	1.00275590	-2.051
KTR=K			
INTERCEP	-1936.13	2291.56802	-0.845
YEAR	1.00785714	1.15560608	0.872
KTR=L			
INTERCEP	-14206.7	1983.80899	-7.161
YEAR	7.18892857	1.00040746	7.186
KTR=M			
INTERCEP	-432.705	351.79781068	-1.230
YEAR	0.23785714	0.17740677	1.341

CONTRACTOR VARIABLE	PARAMETER ESTIMATE	STANDARD ERROR	t VALUE
KTR=N			
INTERCEP	-1777.6	1423.94659	-1.248
YEAR	0.91928571	0.71807658	1.280
KTR=O			
INTERCEP	-5426.68	2215.22529	-2.450
YEAR	2.75964286	1.11710750	2.470
KTR=P			
INTERCEP	-2466.68	884.54506645	-2.789
YEAR	1.26642857	0.44606385	2.839

Cost Per Direct Labor Hour, Data Set C

KTR=A			
INTERCEP	-7270.34	2164.08620	-3.360
YEAR	3.69357143	1.09131876	3.385
KTR=B			
INTERCEP	-4404.2	3959.09556	-1.112
YEAR	2.25285714	1.99651717	1.128
KTR=C			
INTERCEP	9477.75214	1172.59935	8.083
YEAR	-4.745	0.59132565	-8.024
KTR=D			
INTERCEP	-5347.57	3696.42402	-1.447
YEAR	2.74571429	1.86405554	1.473
KTR=E			
INTERCEP	-1912.56	789.67552687	-2.422
YEAR	0.97785714	0.39822245	2.456
KTR=F			
INTERCEP	808.30285714	2223.42875	0.364
YEAR	-0.384286	1.12124439	-0.343
KTR=G			
INTERCEP	-8852.76	4239.15834	-2.088
YEAR	4.50142857	2.13774896	2.106

CONTRACTOR VARIABLE	PARAMETER ESTIMATE	STANDARD ERROR	T VALUE
KTR=H			
INTERCEP	-2594.51	574.17010300	-4.519
YEAR	1.32964286	0.28954605	4.592
KTR=I			
INTERCEP	8200.35607	16777.50022	0.489
YEAR	-4.08393	8.46066146	-0.483
KTR=J			
INTERCEP	2834.90536	1720.40761	1.648
YEAR	-1.39893	0.86757778	-1.612
KTR=K			
INTERCEP	-2628.74	2718.38621	-0.967
YEAR	1.35857143	1.37084459	0.991
KTR=L			
INTERCEP	-17393.7	2800.60353	-6.211
YEAR	8.79785714	1.41230565	6.229
KTR=M			
INTERCEP	-1338.81	388.43439588	-3.447
YEAR	0.69571429	0.19588210	3.552
KTR=N			
INTERCEP	-2973.92	1720.29449	-1.729
YEAR	1.52392857	0.86752073	1.757
KTR=O			
INTERCEP	-6443.45	2629.12575	-2.451
YEAR	3.27357143	1.32583178	2.469
KTR=P			
INTERCEP	-3869.8	738.96563250	-5.237
YEAR	1.97535714	0.37265015	5.301

Cost Per Direct Labor Dollar, Data Set C

KTR=A			
INTERCEP	-736.045	217.95873846	-3.377
YEAR	0.37392857	0.10991358	3.402

CONTRACTOR VARIABLE	PARAMETER ESTIMATE	STANDARD ERROR	t VALUE
KTR=B			
INTERCEP	-444.747	400.34303392	-1.111
YEAR	0.22750000	0.20188746	1.127
KTR=C			
INTERCEP	955.91857143	118.55775471	8.063
YEAR	-0.478571	0.05973704	-8.005
KTR=D			
INTERCEP	-539.759	373.53364741	-1.445
YEAR	0.27714285	0.18836786	1.471
KTR=E			
INTERCEP	-194.204	80.44270950	-2.414
YEAR	0.09928571	0.04056615	2.448
KTR=F			
INTERCEP	81.86821429	224.22013055	0.365
YEAR	-0.0389286	0.11307111	-0.344
KTR=G			
INTERCEP	-892.002	428.11185797	-2.084
YEAR	0.45357143	0.21589089	2.101
KTR=H			
INTERCEP	-262.738	58.26932568	-4.509
YEAR	0.13464286	0.02938442	4.582
KTR=I			
INTERCEP	830.40642857	1693.72810	0.490
YEAR	-0.413571	0.85412367	-0.484
KTR=J			
INTERCEP	288.01214286	174.42796207	1.651
YEAR	-0.142143	0.08796161	-1.616
KTR=K			
INTERCEP	-265.359	273.28350513	-0.971
YEAR	0.13714286	0.13781309	0.995

CONTRACTOR VARIABLE	PARAMETER ESTIMATE	STANDARD ERROR	t VALUE
KTR=L			
INTERCEP	-1756.74	282.60799415	-6.216
YEAR	0.88857143	0.14251531	6.235
KTR M			
INTERCEP	-134.69	39.16113213	-3.439
YEAR	0.07	0.01974842	3.545
KTR=N			
INTERCEP	-298.971	174.10877684	-1.717
YEAR	0.15321429	0.08780065	1.745
KTR=O			
INTERCEP	-649.537	265.02902310	-2.451
YEAR	0.33000000	0.13365047	2.469
KTR=P			
INTERCEP	-391.115	75.18356475	-5.204
YEAR	0.19964286	0.03790395	5.267

Cost Per Direct Labor Dollar, Then-Year Dollars

KTR=A			
INTERCEP	-547.274	189.63232380	-2.886
YEAR	0.27857143	0.09562896	2.913
KTR=B			
INTERCEP	-99.9329	385.32500385	-0.257
YEAR	0.05285714	0.19431407	0.272
KTR=C			
INTERCEP	1205.42821	133.70634866	9.087
YEAR	-0.604643	0.06742626	-8.967
KTR=D			
INTERCEP	-57.475	359.12055639	-0.160
YEAR	0.03357143	0.18109953	0.185

CONTRACTOR VARIABLE	PARAMETER ESTIMATE	STANDARD ERROR	t VALUE
KTR=E			
INTERCEP	-119.957	79.19283911	-1.515
YEAR	0.06178571	0.03993585	1.547
KTR=F			
INTERCEP	180.77392857	190.60502213	0.948
YEAR	-0.0889286	0.09611948	-0.925
KTR=G			
INTERCEP	-481.088	393.13798123	-1.224
YEAR	0.24607143	0.19825405	1.241
KTR=H			
INTERCEP	-82.4293	60.23739228	-1.368
YEAR	0.04357143	0.03037688	1.434
KTR=I			
INTERCEP	1090.98607	1450.58484	0.752
YEAR	-0.545357	0.73150939	-0.746
KTR=J			
INTERCEP	471.81500000	191.88618080	2.459
YEAR	-0.235	0.09676555	-2.429
KTR=K			
INTERCEP	-132.546	233.22530910	-0.568
YEAR	0.07	0.11761230	0.595
KTR=L			
INTERCEP	-1365.5	191.53114847	-7.129
YEAR	0.69107143	0.09658651	7.155
KTR=M			
INTERCEP	-4.59	33.25442967	-0.138
YEAR	0.004285714	0.01676975	0.255
KTR=N			
INTERCEP	-134.967	164.30060827	-0.821
YEAR	0.07035714	0.08285453	0.849

CONTRACTOR VARIABLE	PARAMETER ESTIMATE	STANDARD ERROR	t VLAUE
KTR=O			
INTERCEP	-501.084	230.09805564	-2.178
YEAR	0.25500000	0.11603527	2.198
KTR=P			
INTERCEP	-198.783	70.06888307	-2.837
YEAR	0.10250000	0.03533477	2.901

Note:

INTERCEP = The 'Y' intercept; KTR = Contractor

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The objectives of this study were to determine if "real" cost growth occurred in the defense aerospace industry during the period 1980 to 1986 and if the percentage of overhead costs to total cost increased during the same period. Cost data from sixteen defense aerospace plants were used in this study. The results of the hypothesis tests indicate that there was no "real" cost growth in the industry during the period 1980 to 1986 and that overhead costs did not increase relative to total cost during the same period.

However, when contractors in the sample were tested individually, the results indicate that eight of the sixteen contractors experienced significant cost growth. The conflicting results may be due to the wide dispersion of the data points used in the statistical tests. In turn, this wide dispersion may be caused by the differing variety of aerospace industry segments.

Descriptive statistics computed for the study's sample show that the percentage of direct labor, direct material, other direct charges, and overhead to total cost remained stable over the seven year period. Although overhead costs were not found to be increasing relative to total cost, they still make up the second largest component of total cost (32%) behind direct materials (42%). The size of the overhead cost component combined with the perception that these costs are less controllable than direct costs, provides support for the Department of Defense initiative to have contractors reduce their overhead costs.

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